

FINAL ASSIGNMENT

DESIGN AND CALCULATION OF RAILWAY TUNNEL

**Submitted the requirements in completing undergraduate education on Civil
Engineering of Sultan Agung Islamic University**



ALFIYA ARUM LESTARI

30.2014.03.694

MUETHIA KHARISA S.N.

30.2014.03.855

FAKULTAS TEKNIK JURUSAN TEKNIK SIPIL

UNIVERSITAS ISLAM SULTAN AGUNG

SEMARANG

2018



**YAYASAN BADAN WAKAF SULTAN AGUNG
UNIVERSITAS ISLAM SULTAN AGUNG
FAKULTAS TEKNIK**

Jalan Raya Kaligawe KM. 4 Po. BOX 1054 Telp. (024) 6583584 Ext. 507 Semarang 50112

**APPROVAL PAGE
FINAL ASSIGNMENT**

DESIGN AND CALCULATING OF RAILWAY TUNNEL

By:



ALFIYA ARUM LESTARI
NIM : 30201403694



MUETHIA KHARISA SYAHLMA NUHA
NIM : 30201403855

Have been approved at August , 2018

Supervisor

Co - Supervisor

Ir. M. Faizun Ni'am, MT., Ph.D

Ir. Gatot Rusbintardjo, M.R. Eng MSc., Ph.D

Approved By,
Head of Civil Engineering Department, Engineering Faculty, UNISSULA



Ir. Sentani, ST., M.Sc



**YAYASAN BADAN WAKAF SULTAN AGUNG
UNIVERSITAS ISLAM SULTAN AGUNG (UNISSULA)
FAKULTAS TEKNIK**

Jalan Raya Kaligawe KM 4 Pa. BOX 1054 Telp (074)6583584 Fxt 507 Semarang 50117

BERITA ACARA BIMBINGAN TUGAS AKHIR

Nomor : 21 / A.2 / SA-T / I / 2018

Pada hari ini, tanggal 16 Agustus 2018 berdasarkan Surat Keputusan Ketua Jurusan Universitas Islam Sultan Agung (UNISSULA) Semarang perihal penunjukan Dosen Pembimbing I dan Dosen Pembimbing II :

1. Nama : Ir. M. Faiqun Ni'am, MT., Ph.D
Jabatan Akademik : Lektor
Jabatan : Dosen Pembimbing I
2. Nama : Ir. H. Gatot Rusbintardjo, M.R, Eng, Sc, Ph.D
Jabatan Akademik : Lektor
Jabatan : Dosen Pembimbing II

Dengan ini menyatakan bahwa mahasiswa yang tersebut dibawah ini telah menyelesaikan bimbingan Tugas Akhir/Skripsi :

1. Nama : Alfiya Arum Lestari
Nim : 30201403694
Jurusan : Teknik Sipil
2. Nama : Muethia Kharisa Syahlma Nuha
Nim : 30201403855
Jurusan : Teknik Sipil

telah menyelesaikan Tugas Akhir dengan Judul Design and Calculation of Railway Tunnel.
Dengan tahapan sebagai berikut :

No.	Tahapan	Tanggal
1	Penunjukan Dosen Pembimbing	12 Maret 2018
2	Pengumpulan Data	19 Maret 2018
3	Penyusunan Laporan	6 April-14 Agustus 2018
4	Selesai Laporan	16 Agustus 2018
5	Seminar Tugas Akhir	

Demikian Berita Acara Bimbingan Tugas Akhir ini dibuat untuk diketahui dan dipergunakan seperlunya oleh pihak - pihak yang berkepentingan.

Dosen Pembimbing I

Ir. M. Faiqun Ni'am, MT., Ph.D

Dosen Pembimbing II

Ir. H. Gatot Rusbintardjo, M.R, Eng, Sc, Ph.D



Mengetahui,
Ketua Jurusan Teknik Sipil
Fakultas Teknik UNISSULA

Senjani, ST., MSc.

DECLARATION

The undersigned below :

Name : 1. Alfiya Arum Lestari (30201403694)
2. Muthia Kharisa Syahlma Nuha (30201403855)

Department : Civil Engineering

Hereby declare this our Final Assignment is entitled : **DESIGN AND CALCULATION OF RAILWAY TUNNEL** is a scholarly work free from plagiarism. If later there is proven plagiarism from this final assignment, then I am willing to accept sanction in accordance with applicable legislation.

Semarang, September 2018

By :


Editor I


Alfiya Arum Lestari

Editor II

Muthia Kharisa Syahlma Nuha

Approved :

Supervisor

Ir. M. Faiqun Ni'am, MT., Ph.D

Co-Supervisor

Ir. Gatot Rusbintarjo, M.R.Eng.Sc., Ph.D

ABSTRACT

Railway are constructed in the flat surface, across the river, valley, and mountainous area. In order the train can easily, safely and comfortably move, the track must be as flat as possible. The allowable gradients may be based on the ruling gradient which is the maximum gradient over which a tonnage train can be hauled with one locomotive. In some countries, momentum gradient which is a steeper but shorter gradient may be allowed. This is usually when there is a track gradient is connected to a leveled tangent track that is long enough with no signal between them so that train can build momentum to push through steeper grade than it can be without momentum. Dutch Railway Services allow the maximum gradient 5% or 1 to 200. On that gradient the train considered still able to travel it. If the train should traveled across the highly mountain where the maximum requirement of gradient is impossible to fulfilled, then a tunnel is made to break through the mountain to get the flat gradient of railway. Pay the important of tunnel in the geometry of railway or roadway construction into attention, this final assignment have an objectives : To design and calculation of railway tunnel, To get knowledge on designing and calculating tunnel construction. In this final assignment railway tunnel will be designed and calculated. Of the various types of tunnels, this final assignment will be discuss the railway tunnel as study material. There are two dimensions of tunnels in Indonesia, namely circle tunnels and horseshoe tunnels. The soil type in the tunnel is soft soil because in Indonesia there are many types of soil like that. There are four planning methods in the railroad tunnel, which determine tunnel timing, tunnel width, shear condition, and determine track free space. As for the calculation method using load, check segment, shear force. The results of the calculation of the load on the train tunnel is $g = 12.72 \text{ kN / m}^2$, in vertical pressure at tunnel crown $P1 = 306.12 \text{ kN / m}^2$, vertical pressure at tunnel bottom $P2 = 346.08 \text{ kN / m}^2$, lateral pressure at tunnel crown $q1 = 224.3 \text{ kN / m}^2$, lateral pressure at tunnel bottom $q2 = 368.4 \text{ kN / m}^2$. The results of security checks on the tunnel lining in the shear force get results $\tau = 0.486 \text{ MN / m}^2 < 1.1 \text{ MN / m}^2$, check bolt $\tau = 54.8 \text{ MN / m}^2 < 150 \text{ MN / m}^2$, $S\alpha = 45.5 \text{ kN}$, check of fall $W1 = 333.3 \text{ kN / m}^2$. It can be concluded that the use of the lining segment in the railroad tunnel, apart from depending on the carrying capacity of the land, also depends on the calculation method used.

ABSTRAK

Kereta api dibangun di permukaan datar, melintasi sungai, lembah, dan daerah pegunungan. Agar kereta bisa dengan mudah, aman dan nyaman bergerak, lintasan harus selandai mungkin. Gradien yang diijinkan dapat didasarkan pada gradien yang berkuasa yang merupakan gradient maksimum di mana kereta dapat diangkut dengan satu lokomotif. Di beberapa negara, gradien momentum yang lebih curam tetapi gradien yang lebih pendek dapat diizinkan. Ini biasanya ketika ada lintasan yang terhubung ketinggian lintasan yang cukup panjang tanpa ada sinyal di antara mereka bahwa kereta api dapat membangun momentum untuk mendorong melalui kelas dari pada yang bias tanpa momentum. *Dutch Railway Services* memungkinkan gradient maksimum 5% atau 1 hingga 200. Pada gradient itu, kereta dianggap dapat melakukan perjalanan. Jika kereta api harus melakukan perjalanan melintasi gunung yang sangat tinggi di mana persyaratan maksimum gradient tidak mungkin dipenuhi, maka sebuah terowongan dibuat untuk menerobos gunung untuk mendapatkan gradient kereta api datar. Yang terpenting tentang pembangunan terowongan di jalan kereta api atau konstruksi jalan menjadi perhatian, tugas akhir ini memiliki tujuan: Untuk merancang dan menghitung terowongan kereta api. Dalam tugas akhir ini terowongan kereta api akan dirancang dan dihitung. Dari berbagai jenis terowongan, tugas akhir ini akan dibahas di terowongan kereta api sebagai bahan belajar. Ada dua dimensi terowongan di Indonesia, yaitu terowongan lingkaran dan terowongan tapal kuda. Jenis tanah di terowongan adalah tanah lunak karena di Indonesia ada banyak jenis tanah. Ada empat metode perencanaan di terowongan kereta api, yang menentukan waktu terowongan, lebar terowongan, kondisi geser, dan menentukan ruang bebas jalur. Adapun metode perhitungannya menggunakan beban, check segmen, gaya geser. Hasil perhitungan pada terowongan kereta adalah $g = 12,72 \text{ kN} / \text{m}^2$, pada tekanan vertical pada terowongan mahkota $P1 = 306,12 \text{ kN} / \text{m}^2$, tekanan vertical di bawah terowongan $P2 = 346,08 \text{ kN} / \text{m}^2$, tekanan lateral pada terowongan mahkota $q1 = 224,3 \text{ kN} / \text{m}^2$, tekanan lateral di bawah terowongan $q2 = 368,4 \text{ kN} / \text{m}^2$. Hasil pemeriksaan keamanan pada lapisan terowongan dalam gaya geser mendapatkan hasil $\tau = 0,486 \text{ MN} / \text{m}^2 < 1,1 \text{ MN} / \text{m}^2$, periksa baut $\tau = 54,8 \text{ MN} / \text{m}^2 < 150 \text{ MN} / \text{m}^2$, $S\alpha = 45,5 \text{ kN}$, pengecekan jatuh $W1 = 333,3 \text{ kN} / \text{m}^2$. Dapat disimpulkan bahwa penggunaan lining segment pada terowongan kereta api selain tergantung dari daya dukung tanahnya juga tergantung dari metode perhitungan yang dipergunakan.

MOTTO

(Alfiya Arum Lestari)

“Dan janganlah kau berputus asa dari rahmat Allah. Sesungguhnya tidaklah seseorang berputus asa kecuali orang – orang yang kafir”

(QS. Yusuf : 87)

- (٤١) - الْأَوْفَى الْجَزَاءُ يُجْزَاهُ ثُمَّ - (٤٠) - يُرَى سَوْفَ سَعْيِهِ وَأَنَّ - (٣٩) - سَعَى مَا إِلَّا لِلْإِنْسَانِ لَيْسَ وَأَنَّ

“Dan bahwa manusia hanya memperoleh apa yang telah diusahakannya, dan sesungguhnya usahanya itu kelak akan diperlihatkan (kepadanya), kemudian akan diberi balasan kepadanya dengan balasan yang paling sempurna.”

(QS An-Najm 39-41)

“Barang siapa yang menginginkan dunia maka wajiblah ia memiliki ilmunya dan barang siapa yang ingin (selamat&bahagia) diakhirat maka wajiblah ia memiliki ilmunya pula dan barang siapa yang menginginkan kedua-duanya maka wajiblah ia memiliki ilmu kedua-duanya pula”

(HR. Bukhori Muslim)

(Muethia Kharisa SN)

“Behold along with the difficulty there is relief. Therefore when you're done (do something else). And hope to the Lord.

(QS. Al Insyirah : 6-8)

“Everything went well even though everything seems to go wrong at all if you are honest with yourself. Instead, everything is not good for you even if everything looks right, if you are not honest with yourself”.

(Mahatma Gandhi)

“I dedicated this final assignment to the knowledge of airport and runway engineering as my worship to Allah SWT”

ACKNOWLEDGEMENT

Alhamdulillahirabbil'alamin, Innalhamdulillah nahmaduhu wa nasta'iyuhu. Upon Ridho and Rahmat Allah Subhana wa Ta'ala this final assignment report can be completed.

In preparing this report, I was contact with many people, researches, academicians, and practitioners. They have contributed towards my understanding and thoughts. In particular, i wish to express my sincere appreciation to my main study supervisor, Ir. M. Faiqun Ni'am, MT., Ph.D or for his encourages, guidance, criticism, and friendship. I an also very thankful to my Co – supervisor, Ir. H. Gatot Rusbintardjo, M.R.Eng., MSc., Ph.D., for his guidance, advice and motivation. Without their continued support and interest, this final assignment report would not have been the same as presented here.

My special thanks are addressed to Dean of the Engineering Faculty of UNISSULA, Bapak Rachmad Mudiyo, MT., Ph.D. and Head of Department of Civil Engineering, Faculty of Engineering UNISSULA, Bapak Ari Sentani, ST., MSc., for permission, to take the final assignment as the requirement for reaching Bachelor Degree in Civil Engineering in Faculty of Engineering UNISSULA.

Very special thanks are given to my beloved parents, my father Susila and my mother Indah, their patience, prayers and understanding during this study were always a blessing. Also my sister Nurul anda my brother Yoga who always give me support and pray.

Of course for Muethia Kharisa Syahlma Nuhaas partner who have worked hard and fought together to resolve this final assignment.

Special thanks to all of my big family (Prasodjo big Family and Sutrisno big Family) for support, motivate and pray for the success of this final assignment.

Thanks to All of my friends in Faculty of Civil Engineering 2014 especially class D for their support. Also to all of my Acceleration friend 2014, who always fought together and give me support. Thanks to my best Friends, Aldila, Zaimah, Sari, Tantri, Ardi, Wahyu, Wisnu, Devi, Lina, Vyxy, Tami and Ifa who always caring and provide support.

Semarang, August 2018

Alfiya Arum Lestari

ACKNOWLEDGEMENT

Alhamdulillah rabbil'alamin, Innalhamdulillah nahmaduhu wa nasta'iyuhu. Upon Ridho and Rahmat Allah Subhana wa Ta'ala this final assignment report can be completed.

In preparing this report, I was contact with many people, researches, academicians, and practitioners. They have contributed towards my understanding and thoughts. In particular, i wish to express my sincere appreciation to my main study supervisor, Ir. M. Faiqun Ni'am, MT., Ph.D for his encourages, guidance, criticism, and friendship. I an also very thankful to my Co – supervisor, Ir. H. Gatot Rusbintardjo, M.R.Eng MSc., Ph.D., for his guidance, advice and motivation. Without their continued support and interest, this final assignment report would not have been the same as presented here.

My special thanks are addressed to Dean of the Engineering Faculty of UNISSULA, Bapak Rachmad Mudiyo, MT., Ph.D. and Head of Department of Civil Engineering, Faculty of Engineering UNISSULA, Bapak Ari Sentani, ST., MSc., for permission, to take the final assignment as the requirement for reaching Bachelor Degree in Civil Engineering in Faculty of Engineering UNISSULA.

Very special thanks are given to my beloved parents, my father Noor Al Hidayat and my mother Karmini Umi Hanik (Almh) and my mother Maghfirotn Mujahadah, their patience, prayers and understanding during this study were always a blessing. Also my brother Nuha, my sister Zulva and my young sister Ashna who always give me support and pray.

Of course for Alfiya Arum Lestari as partner who have worked hard and fought together to resolve this final assignment.

Special thanks to all of my big family (Soedarno big family and Hardi big family) for support, motivate and pray for the success of this final assignment.

Thanks to All of my friends in Faculty of Civil Engineering 2014 especially class D for their support. Also to all of my Acceleration friend 2014, who always fought together and give me support. Thanks to my best Friends, Lia, Novi, Muna, Ika, Syamsiyah, Alfiya, Arga, Falah, Thifa, Isnah, Yulian, Himma who always caring and provide support. Also my Nephews Kevin, Shaka and Icha who always entertaining and making the atmosphere of the house is always crowded.

Semarang, August 2018

Muethia Kharisa Syahlma Nuha

TABLE OF CONTENTS

TITLE PAGE	i
APROVAL PAGE	ii
PROCESS VERBAUX (BERITA ACARA)	iii
ABSTRACT	iv
ABSTRAK	v
MOTTO	vi
DEDICATION	vii
ACKNOWLEDGEMENT	viii
LEMBAR ASISTENSI	xii
TABLE OF CONTENTS	xx
LIST OF TABLE	xxvi
LIST OF FIGURE	xxix
LIST OF ABBREVIATIONS	xxxii
LIST OF APPENDICES	xxxvi

CHAPTER 1 INTRODUCTION

1.1. Background and Problem Statement	1
1.2. Problem Statement	4
1.3. Objectives of the Study.....	4
1.4. Scope of the Study	4

CHAPTER 2 LITERATURE REVIEW

2.1. Introduction	5
2.2. Tunnel.....	5
2.3. Type of Soil Tunnel.....	6
2.3.1. Rock Tunnel.....	6
2.3.2. Soft Ground Tunnel.....	8
2.4. The Type based on it Tunnel	8
2.4.1. Traffic Tunnel	8

2.4.2. Transport Tunnel	9
2.4.3. Mine Tunnel	9
2.5 Tunnel Construction Methode	10
2.5.1 Cut and Cover.....	11
2.5.2 Tunnel Boring Machine (TBM)	11
2.5.3 Slurry Shield Boring Machine	13
2.5.4 EPB Shield Boring Machine	13
2.6 Lining Tunnel	15
2.7 Soil Classification.....	16
2.7.1 Unified Soil Classification System	16
2.7.2 AASTHO Soil Classification	17
2.8 Railway Track Structure	21
2.8.1 Rail	21
2.8.2 Sleepers	22
2.8.3 Fasteners.....	23
2.8.4 Ballast.....	25
2.8.5 Subballast	25
2.8.6 Subgrade.....	25
2.9 Parameters for Tunnel Design and Calculation	26
2.9.1 Train Load	26
2.9.2 Soil Pressure.....	28
2.9.3 Earthquake Load	30

CHAPTER 3 DESIGN AND METHODOLOGY

3.1 Introduction	33
3.2 Preliminary Design	33
3.2.1 Determine Dimension of Tunnel.....	33
3.2.2 Determine the Thickness of Lining Tunnel.....	36
3.3 Design Method of Railway Tunnel	37
3.3.1 General and Design Principle.....	37
3.3.2 Loads	38

3.3.2.1	Ground Pressure	38
3.3.2.2	Water Pressure	41
3.3.2.3	Dead Load	42
3.3.2.4	Surcharge	42
3.3.2.5	Subgrade Reaction	42
3.3.2.6	Loads During Construction Stage	44
3.3.2.7	Effect of Earthquake	44
3.3.3	Materials.....	44
3.3.3.1	Modulus of Elasticity	45
3.3.3.2	Stress Strain Curve.....	45
3.4	Safety Factors	46
3.5	Structural Calculation	46
3.5.1	Model of Computation	46
3.5.2	Evaluation of Joints.....	47
3.5.3	Check the Safety of Section	48
3.6	Structural Details	48
3.7	Productions of Segments	51
3.8	Secondary Lining.....	51
3.8.1	General	51
3.8.2	Thickness.....	51
3.8.3	Computation of Members Force	51
3.8.4	Property Lining Data.....	52
3.9	Determine of Design Parameters	53
3.9.1	Shear Force.....	53
3.9.2	Check of Bolt between A-type Segments and B-type Segment.....	54
3.9.3	Check of Bolt between B-type Segments and K-type Segment.....	54
3.9.4	Check of Fall of K-type Segment.....	54
3.9.5	Check of Fall of Segmental Ring	55
3.10	Earthquake Response of Tunnel Railway Structure	55
3.10.1	Simplified Equations for Axial Strains and Curvature	56
3.10.2	Proposed seismic design philosophy for tunnel.....	58

CHAPTER 4 DESIGN AND CALCULATION

4.1	Introduction	60
4.2	Design of Tunnel Railway	60
4.2.1	Dimensions of Railway Tunnel	60
4.2.2	Specification of Concrete.....	61
4.3	Soil Conditions	61
4.4	Design Method.....	62
4.4.1	Load Condition	62
4.4.1.1	Dead Load	63
4.4.1.2	Vertical Pressure at Tunnel Crown	63
4.4.1.3	Vertical Pressure at Tunnel Bottom	64
4.4.1.4	Lateral Pressure at Tunnel Crown.....	64
4.4.1.5	Lateral pressure at Tunnel Bottom.....	64
4.4.2	Computation of Members Force	65
4.4.3	Result of Computation	66
4.5	Check of Safety of Segmental Lining.....	66
4.5.1	Check of Segment	66
4.5.2	Check Against Shear Force.....	68
4.5.3	Check of Joint	68
4.5.4	Check of Bolt	69

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

5.1	Conclusions	73
5.2	Recommendations	73

REFERENCES..... xxii

APPENDIX xxvi

LIST OF TABLE

Table 2.1. Soil Symbols	17
Table 2.2. Soil Classification AASTHO	20
Table 2.3. Devision of Railway Classes (PM No. 60 of 2012).....	28

LIST OF FIGURE

Figure 1.1. Cross section of railway structure.....	1
Figure 1.2. Track gradient.....	2
Figure 1.3. Tunnel.....	3
Figure 2.1 Rock Tunnel.....	7
Figure 2.2 Soft Ground Tunnel.....	8
Figure 2.3 Traffic Tunnel.....	9
Figure 2.4 Mine Tunnel.....	10
Figure 2.5 Tunnel Cut and Cover.....	11
Figure 2.6 Tunnel Boring Machine (TBM).....	12
Figure 2.7 Scheme of Operational TBM.....	13
Figure 2.8 Slurry Boring Machine.....	14
Figure 2.9 EPB Shield Boring Machine.....	14
Figure 2.10 Lining Tunnel.....	15
Figure 2.11 Soil Classification Chart USCS.....	19
Figure 2.12 Liquid Limit and Plasticity Index Range.....	20
Figure 2.13 Rail Profile.....	22
Figure 2.14 (a) Concrete Sleeper (b) Wood Sleeper.....	24
Figure 2.15 (a) Type of Fastener.....	27
Figure 2.15 (b) Type of Fastener.....	28
Figure 2.16 Wheel Load Distribution on The Bearing.....	30
Figure 2.17 Example of notation used in the guidelines.....	31
Figure 2.18 Ground Pressure Acting on Lining.....	33
Figure 3.1. Flowchart Design and Calculation of Tunnel.....	35

ABBREVIATIONS

T	= Thickness
A	= Area
E	= Modulus of elasticity
I	= Moment of inertia of area
EI	= Flexural rigidity
M	= Moment
N	= Axial force
S	= Shearing force
D	= Diameter of lining
R _o	= Outer radius
R _c	= Radius of centroid
R _i	= Inner radius of the lining
γ	= Weight of soil
γ'	= Submerged unit weight of soil
γ_w	= Unit weight of water
γ_c	= Unit weight of concrete
H	= Overburden
$\gamma_w \times H_w$	= Groundwater pressure at crown of lining
P _o	= Surcharge
W	= Weight of lining per meter in longitudinal direction
p _g	= Dead Load
P _{e1}	= Vertical earth pressure at crown of lining
P _{w1}	= Vertical water pressure at crown of lining
q _{e1}	= Horizontal earth pressure at crown of lining
q _{w1}	= Horizontal water pressure at crown of lining
P _{e2}	= Vertical earth pressure at bottom of lining

- P_{w2} = Vertical water pressure at bottom of lining
- q_{e2} = Horizontal earth pressure at bottom of lining.
- q_{w2} = Horizontal water pressure at bottom of lining
- p_w = Water pressure.
- Λ = Coefficient of lateral earth pressure.
- k = Coefficient of subgrade reaction.
- δ = Displacement of lining.
- p_k = Subgrade reaction/la reaction/Bettung.
- C = Cohesion of soil / La cohesion du sol / Kohäsion vom Boden.
- \emptyset = Angle of internal friction of soil.
- f_{ck} = Nominal strength of Concrete (Characteristic Compressive Strength of Concrete)
- f_y = Yield strength of steel
- E_s = Modulus of elasticity of steel

