How to Cite:
Arjmand, M. (2022). Effect of water-based polymers of cement base with fly ash on the stress and strain of concrete in the metro segment. *International Journal of Health Sciences*, *6*(S7), 1270–1286. https://doi.org/10.53730/ijhs.v6nS7.11532

Effect of water-based polymers of cement base with fly ash on the stress and strain of concrete in the metro segment

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Abstract---This Research Aimed To Examine The Effect Of Water-Based Polymers Of Cement Base With Fly Ash On The Displacement Of Concrete In The Urban Metro Segment. The Mix Variants Of The Study Are Comprised Of 2 Water/Cement Ratios Of 0.5 And 0.45, Each Of Which Has Four Weight Ratios (5%, 10%, 15%, 20%) Of Fly Ash Added To The Cement, Amassing Eight Different Mixes. Moreover, 150x150x150 Mm Cubic Molds Were Used For Sample Preparation And Sampling. Nine Cubic Samples Were Retrieved From Each Mixing Scheme. After Removing The Samples From The Mold, They Were Compressed For 7, 28 And 42 Days. The Findings Indicated That The Concrete Samples Of The Variant With The Water/Cement Ratio Of 0.45 And Fly Ash/Cement Ratio Of 15% Exhibited Maximum Strength. The Maximum Displacement Values Before The Earthquake Were 12.4 Cm In The Vertical Direction For Concrete With Fly Ash And 18.4 Cm For The Applied Concrete. After The Earthquake, These Values Were 25.4 Cm And 36.4 Cm, Respectively. Also, The Displacement Values In The X Direction Have Decreased By 5 To 6 Cm At Different Loading Steps. The Displacement Values In The Z Direction Show A Decrease Of 6 To 7 Cm In The Gravity And Dead Load Steps And 11 Cm In The Seismic Loading Steps.

Keywords---*Water-Based Polymers Of Cement Base, Fly Ash, Urban Subway Segment.*

Introduction

The High Energy Costs Involved In The Production Of Portland Cement And The Pollutants Produced And Propagated In The Aftermath Have Rationalized The Efforts To Reduce Portland Cement Clinker Production And Thus Find Materials As Substitutes. Pozzolans Have Garnered Considerable Academic Interest As A Complete Alternative To Portland Cement In Concrete To Produce Geopolymer Cement And Concrete (Cement-Free Concretes) [1]. Geopolymer Concretes Use

Manuscript submitted: 9 April 2022, Manuscript revised: 18 June 2022, Accepted for publication: 27 July 2022

Geopolymer Cement Paste To Bond Fine And Coarse Grains. Geopolymer Concrete Can Produce Prefabricated Parts And Structural And Non-Structural Elements And Concrete Pavements, Stabilize Toxic Waste And Produce Heat- And Corrosion-Resistant Products And Environments [2].

The Production And Use Of Geopolymer Cement Have Been Highly Neglected By The Academic Circles For Several Decades. Geopolymers Have Been Proposed As Alternatives To A Wide Range Of Building Materials Since The Late Twentieth Century Owing To Their Optimal Properties And High-Yielding Performance. The Extensive Application Of These Materials In Various Engineering Fields During The Last Decade Has Driven Many Studies In The Literature. Geopolymers Are A Group Of Durable Cementitious Materials That Harden At Temperatures Below 100 °C. Davidowitz Stated In The 1970s That Geopolymers Are A New Group Of Three-Dimensional Aluminosilicate Materials [3]. The Production Of Geopolymer Cement And Concretes Has A Perceivably Less Detrimental Environmental Impact

Than Conventional Portland Cement.

Furthermore, Base Materials (E.G., Aluminosilicate Materials) Are Naturally Present In Many Industrial Wastes. Natural Aluminosilicate Materials Are The Same Natural Pozzolans Abundantly Found In Many Parts Of The World, Iran Being No Exception. Synthetic Aluminosilicates Are Also By-Products Of Industrial Plants. It Has Been Claimed That Geopolymer Cement Accounted For 47% Of The Cement Market In 2016 [4].

Given Their Pozzolanic Compounds, The Application Of Fly Ash In Corrosion-Prone Concrete Projects Relieves Some Of The Concrete Problems That Lead To Reduced Structural Durability, Improving The Efficacy Of The Concrete. Some Of These Effects Are Owing To Their Physical Properties, Including Roughness And Particle Shape, While Others Stem From The Chemical Interactions Of Pozzolan With Cement. Regardless Of The Economic Aspect Of Concrete Mixtures Using Fly Ash, The Performance Of This Material In Improving The Quality Of Concrete And Increasing Its Durability Against Corrosion-Prone Environments Has Led To Its Greater Application In Such Environments. When Using Fly Ash, Water Consumption Is Significantly Less Than When Using Only Cement [5-6]. For This Reason, The Resulting Material Has A Higher Density And Has Fewer Pores For The Penetration Of Water Or Other Climate-Related Corrosive Factors [7].

Saadat Khosh Et Al. (2017) Examined The Effect Of Class F Fly Ash On The Elastic Modulus And Fracture Mechanics Of Concrete. Their Findings Indicated That The Average Coefficients Of Laboratory Results For Concrete Fracture Energy With Class F Fly Ash For The Europe And Japan Regulatory Relations Are 0.62 And 1.08, Respectively. Moreover, The European Regulations Relations For Concrete Fracture Energy And Class F Fly Ash Are Deemed Non-Conservative For 92% Of The Data, The Japanese Equivalent Of 58% Of Data [8]. Shahrokh And Pir Mohammadi Alishah (2017) Evaluated The Effect Of Natural Pozzolans In Different Grades Of Cement On The Compressive Strength Of Concrete. The Results Indicated That Increasing The Pozzolan Reduces The Strength Of Concrete. Furthermore, The Results Indicated That The Level Of Strength Decreases As The Concrete Content Increases [9]. Pejmanfar Et Al. (2016)

Examined The Comparative Effect Of Fly Ash And Zeolite On The Mechanical Properties Of Concretes, The Results From Which Indicated That At The Age Of 28 Days, Fly Ash And Zeolite Powders Improved The Compressive Strength And Tensile Strength Of Plastic Concrete By Performing A Pozzolanic Reaction [10].

Ramezanianpour Et Al. (2012) Established The Efficient Performance Of Using Zeolite In Self-Compacting Concrete Mixes On Fresh Concrete Properties Such As Flowability, Permeability, And Durability. By Increasing The Replacement Percentage Of Zeolite Above 30%, The Authors Further Reported An Improvement In Separation Resistance And Improved Durability Properties Of Self-Compacting Concrete Mixtures [11]. Dousti Et Al. (2011) Performed A Study On The Durability Of Concrete In The Persian Gulf Environment. They Concluded That The Durability Of Reinforced Concrete Structures In Aggressive Areas Such As The Persian Gulf Is The Biggest Challenge That Such Structures Face [12]. Alkhaleefi Et Al. (2002) Examined The Behavior Of Polymer-Cement Concrete And The Effects Of Employing Epoxy In Modifying Concrete Properties [13].

Turkmen Et Al. (2010) Examined Flowability, Strength And Wave Velocity In Self-Compacting Concrete Containing Zeolite And Zeolite With A Fixed Superplasticizer. They Reported That Self-Compacting Concretes Can Be Produced With Only 10% Of Zeolite. Cioffi Et Al. (2010) Examined The Effects Of Fly Ash, Silica Fume And Two Types Of Zeolites With Different Constituent Oxides. Two Different Mixtures Were Considered, As Zeolite Up To 40% Was Used As A Substitute For Cement. The Results Revealed That Self-Compacting Concrete Containing Zeolite Could Be Produced With Slump Flow Values Of 60 To 70 Cm [15]. Hossain (2008) Reported That Using 28-Day-Old Pumice Natural Pozzolan Reduces The Compressive Strength. As The Replacement Rate Of Pumice Increased Up To 30%, The Rate By Which Compressive Strength Increased Of Concrete Is Reduced Increases.

Yegiter Et Al. (2007) Showed That At A Constant Water-To-Cement Ratio, The Strength Of Concrete Decreases As The Cement Content In The Mixture Increases. Dahir Et Al. (2006) Attributed The Effect Of Cement Content Cement To The Microstructure Of Concrete [18].

Studies In Geopolymer Concrete Have Proven That The Factors Affecting The Mechanical Properties And Durability Of These Concretes Are Not Fully Established Yet. Furthermore, Little Is Known Regarding The Behavior Of Geopolymer Mortars And Concretes Made With Natural Pozzolans. The Behavior And Properties Of Geopolymer Cement Paste Significantly Affect The Properties Of Geopolymer Mortars And Concrete [19]. As Such, This Study Aims To Examine The Effect Of Water-Based Polymers Of Cement Base With Fly Ash On Improving The Mechanical Properties Of Concrete In The Urban Metro Segment.

Research Methodology

Given The Ever-Increasing Demand For Intra-City Trips In Tabriz And The Subsequent Need To Use The Railway Transportation System To Alleviate Traffic Loads, Studies Of Phases One And Two Of Tabriz City Trains Began In 2001 And

The Tabriz Urban Railway Network Was Designed With Four Lines And Route Length Of 60 Km As Follows (Figure 1).

Line 1: 17.2 Km Route Length, 18 Stations, Starting From Ael Goli Square And Ending At Laleh Alley Through Shahid Bakri Boulevard And 29 Bahman, Imam Khomeini Street, Mohagheghi Crossroads, Golestan Garden And Khayyam Street. About 8 Km Of The Route Is Designed As A Deep Tunnel.

Line 2: Route Length Of 22.4 Km, 20 Stations, Starting From Gharamak Lands (Organic Fertilizer Factory), Going Through Vahdat Street And Gharamalek Square (The First Station), Akhooni Street, Ghods Street, Mohagheghi (Interchange With Line 1), Daneshsara Square, Abbasi Street, Shahid Fahmideh Square, Valiasr 3-Way Intersection, Ostad Moin Square, And Finally To Basij Square.

Line 3: Route Length Of 15 Km, 14 Stations, Starting From Tabriz International Airport And Ending At The Big Intercity Bus Terminal In Tabriz, Next To Shahid Kasaei Highway, Going Through Azerbaijan Square And Enghelab Street, Daneshsara Square And Artesh Street.

Line 4: Route Length Of 10 Km, 10 Stations In A Semi-Circular Shape In The City Center, Connecting The Above Three Lines.

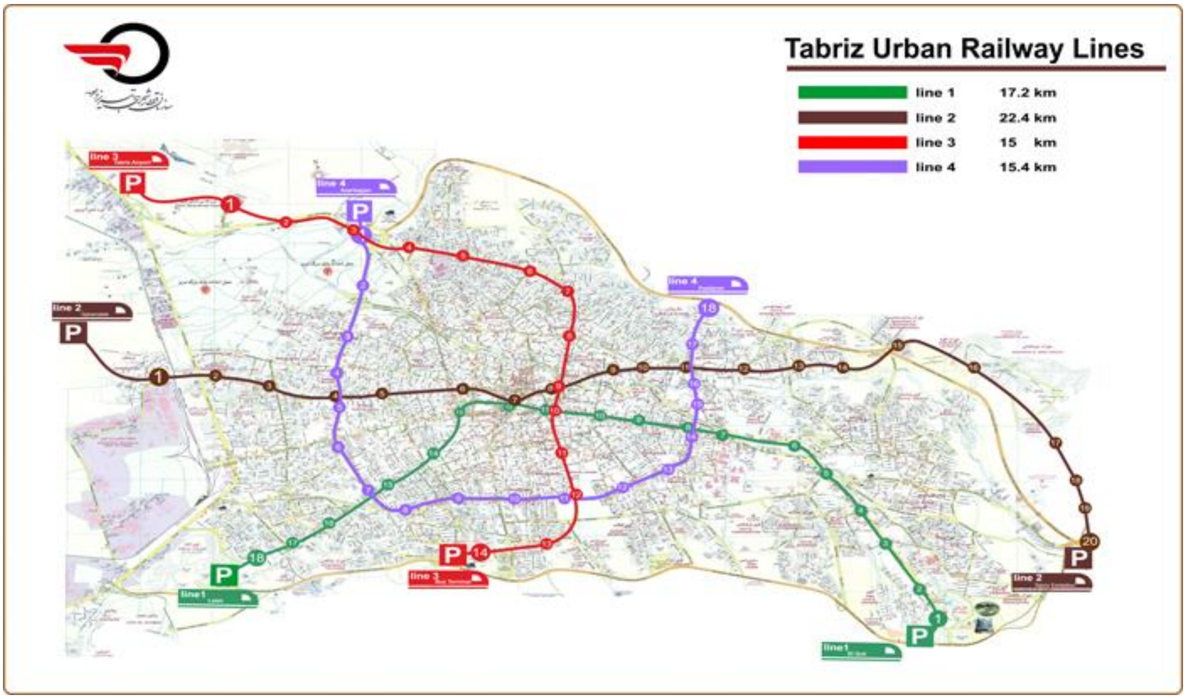

Figure 1: Tabriz Urban Railway Lines [19]

In Terms Of Lithology, Most Of The Geological Formations Of Azerbaijan Are Comprised Of Sedimentary, Volcanic And Evaporite Ones. The Most Important

Traceable Earthly Materials In Most Of Azerbaijan Are Limestone, Marl, Red Sandstone, Detrital And Igneous Rocks And Evaporitic Sediments, Including Gypsum And Salt Layers, As Well As Shale Layers And Thin Veins Of Coal (Lignite). The Age Of These Formations Dates Back To The First And Second Geological Periods, And Most Of Them Belong To The Cretaceous Period [19].

With About 22.4 Km, Line 2 Of The Tabriz Metro Is Currently The Longest Route Of The Tabriz Metropolitan Railway Network. This Line Includes 20 Stations Starting From Gharamak Lands (Organic Fertilizer Factory), Going Through Vahdat Street And Gharamalek Square (The First Station), Akhooni Street, Ghods Street, Mohagheghi (Interchange With Line 1), Daneshsara Square, Abbasi Street, Shahid Fahmideh Square, Shahrak Nasr, Marzdaran, Azad University, Tabriz International Fair, And Finally Basij Square [19].

Geotechnical Parameters Of C_2 Station Section In Area Number 1 Of Subway Line 2

This Section Has Been Selected At The Site Of Station C2 And The Intersection Akhoni Of Jahad Boulevard. Section 4 Or C_2 Is Of Structurally Paramount Significance. In This Section, The Presence Of Bridge Piers Near The Tunnel Structure And Evaluating The Deformation Effects Due To The Loading Of Bridge Piers On The Structure Have Been Selected. Figure 2 Shows The Approximate Location Of Section 4 Or Station C2 And The Aerial Image Of This Section.

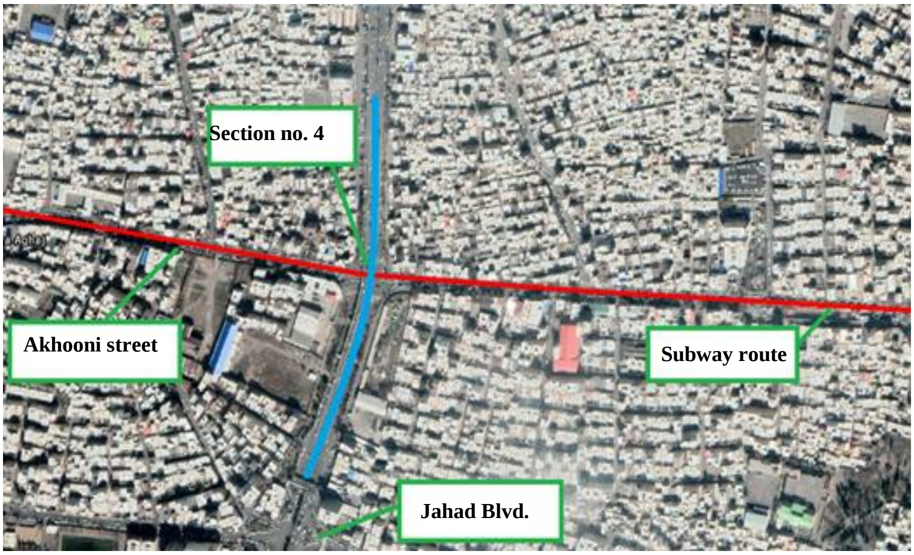

Figure 2: Approximate Position Of Section 4 Of Station C_2 In Area Number 1 Of Subway Line 2

Based On The Excavations Carried Out In The Area Of The C_2 Station, All Subsurface Layers Are Composed Of Alluvial Sediments. None Of The Boreholes Dug At This Site Have Been Hit By Rock Layers. Sand Layers Are Mainly Characterized By SM Classification And ML And CL Classification Fine-Grained

Layers. The Thickness Of The Soil Layer Is Less Than 1 Meter. Groundwater Depth Is Observed Between 6.5-8 Meters, And None Of The Boreholes Made Contact With Under Pressure Aquifers.

Due To The Properties Of Elasticity, Soil Type And Groundwater Level, The Possibility Of Liquefaction In An Earthquake With Amax = 0.35 And M = 7.5 Is Well-Grounded. The Geotechnical Parameters Of The Soil Of This Site Are

Presented In Table 1.

Table 1: Geotechnical Parameters Of Critical Section No. 4 Of C2 Station In Area Number 1 Of Subway Line 2

Layer (Depth In Meters)	**Silt Layer (0-5)**	**Sand Layer (5-8)**	**Silt Layer (8-25)**	**Sand Layer (25-30)**	**Silt Layer (30-35)**
Γ(Gr/Cm3)	1.65~1.75	1.65~1.75	1.7~1.75	1.7~1.8	1.7~1.75
K (Cm/S)	1E-4~1E-5	1E-3~1E-4	1E-5~1E-6	1E-4~1E-5	1E-5~1E-6
C_{uu}(Kg/Cm^2)	0.1~0.15	-	0.1~0.15	-	0.15~0.2
C_{cu}(Kg/Cm^2)	0.05~0.07	0.02~0.05	0.05~0.08	0.05~0.10	0.07~0.10
Φ (Deg)	18~22	23~26	22~26	26~28	25~27
E(Kg/Cm^2)	100~150	150~250	150~250	250~350	200~300
V	0.35~0.4	0.32	0.35~0.4	0.32	0.35
K_0	0.69	0.61	0.59	0.55	0.56
K (Mpa^{-1})	0.2~0.25	-	0.15~0.2	-	0.05~0.1

Also, The Specifications Of The Steel Section Used In The Segment Are Presented In Table 2. Fifteen #12 Rebars Are Used In Each Reinforcement Grid. Table 3 Presents The Characteristics Of Concrete Used In The Segments.

Table 2: Specifications Of Rebars Used In The Segment

Type Of Steel	Class	S 400 (Class C)
Yield Strength	f_{yk}	400 Mpa
Design Strength	f_{dk}	350 Mpa
Tensile Strength	f_t	460 Mpa
Modulus Of Elasticity	E	210 Gpa

Table 3: Specifications Of Concrete Used In The Subway Tunnel

Type Of Concrete	Class	**C45/55**
28-Day Compressive Strength	Fck	Mpa40
Modulus Of Elasticity	E	40 Gpa
Poisson Coefficient	**V**	0.2
Density Of The Concrete	P	2500 (Kg/M3)
Concrete Fracture Modulus	Fr	Mpa4/42

In The Segment Analysis Stage, Important And Sensitive Sections Should Be Examined According To The Depth Of The Layers, Special Structures, Groundwater, And Characteristics Of Soil Materials, Among Others. Considering The Sensitivity Of The Areas Along The Route, The C_2 Section Was Selected For Further Analysis Due To The Akhoni Bridge Piers Near The Tunnel Structure.

The Geometric Characteristics Of A Type Of Parallelogram Tetragonal Segment Are Shown In Table 4. The Maximum Displacement In The Tunnel Roof And The Ground Level Is Presented In Table 4, Derived From The Information Obtained From The City Train Organization From The Segment Design Analysis For This Section.

Table 4: Specifications Of The Segment

Geometric Shape Of The Segment	Tetragonal Parallelogram
Internal Diameter Of The Segment (Meters)	8.48
Number Of Segments İn A Ring	1+1+7
Length Of A Segment (Meters)	4.12
Width Of A Segment (Meters)	1.5
Segment Thickness (Cm)	35
Segment Volume (Meters)	2.16

Table 5: The Maximum Displacement In The Tunnel Roof And Ground Level In Section C2

Section	Displacement İn Tunnel Roof (Cm)	Displacement İn Ground Level (Cm)
4	3.9	0.9

The Mixture Variant Employed In This Research Are Consisted Of Water/Cement Ratios Of 0.45 And 0.5, Each With Four Fly Ash/Cement Weight Ratios (5%, 10%, 15%, 20%). 150 X 150 X 150 Mm Cubic Molds Are Used For Sample Preparation And Sampling. Nine Cubic Samples Were Taken From Each Mixing Scheme. After Removing The Samples From The Mold, They Were Compressed By 7, 28 And 42 Days Of Age. Concrete Samples Have Shown Maximum Strength Based On The Results In The Ratio Of Water To The Cement Of 0.45 And Fly Ash To The Cement Of 15% (CU4515). Details Of This Mixing Scheme Can Be Seen In Table 6.

Table 6: Specifications Of Mixing Designs

Variant	CA (Kg)	FA (Kg)	C (Kg)	P (Kg)	آبW (Kg)
CU4500	37.38	25.75	17.31	0.00	7.84
CU4005	37.38	25.36	16.44	0.86	7.84
CU4510	37.38	24.98	15.78	1.73	7.84
CU4515	37.38	24.59	14.71	2.59	7.84
CU4520	37.38	24.20	13.84	3.46	7.84
CU5000	37.38	27.19	15.58	0.00	7.83
CU5005	37.38	26.85	14.80	0.78	7.83
CU5010	37.38	26.50	14.02	1.55	7.83
CU5015	37.38	26.15	13.24	2.33	7.83
CU5020	37.38	25.80	12.46	3.11	7.83

Numerical Modeling

Figure 3 Illustrates The General Geometry Of The Model Under Study. The Mechanical Properties Of The Materials Used In This Modeling Are Defined In The Property Module. The Mechanical Properties Of The Ten Soil Layers Have Been Selected Based On Reports And In Accordance With The Behavioral Model Of Moher Columbus. The Mechanical Behavior Of The Steel Is Also Modeled According To Table 7. Also, The Specifications Of The Concrete Used (Table 8), Which Is The Same As Water-Based Concrete Of Cement Base With Fly Ash, Were Inputted Into The Software Program. The Default Thickness Of The Concrete Section Is 35 Cm, And The Reinforcement Is Modeled With Rebars With A Diameter Of 10 Mm From Every 15 Cm On Each Side At The Same Depth.

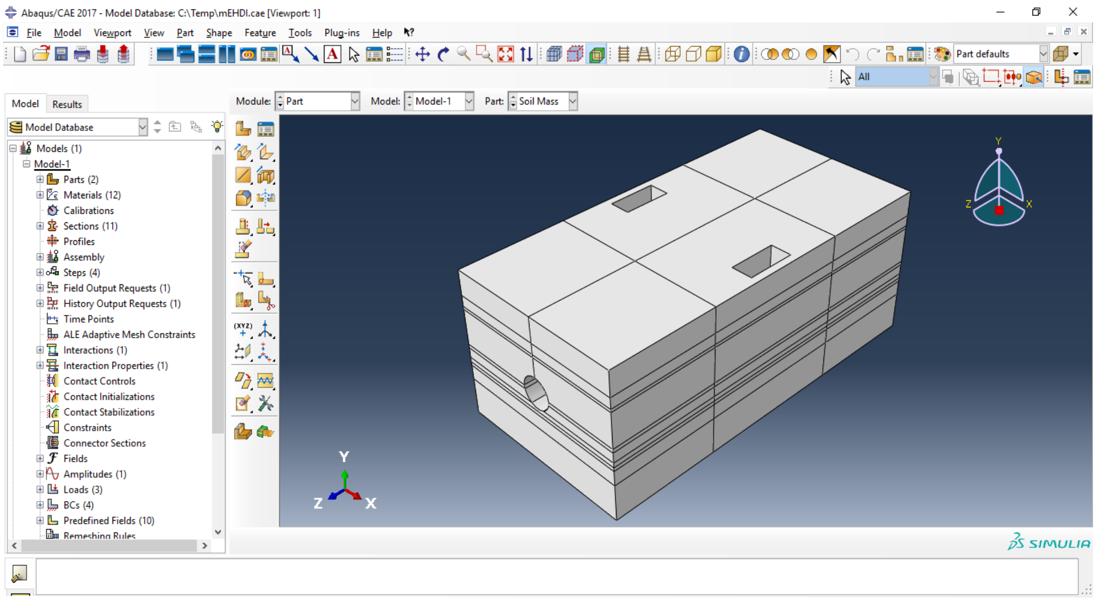

Figure 3: General Geometry Of The Studied Model

Table 7: Rebar Specifications Used In The Segment

Type Of Steel	Class	S 400 (Class C)
Yield Strength	f_{yk}	400 Mpa
Design Strength	f_{dk}	350 Mpa
Tensile Strength	f_t	460 Mpa
Modulus Of Elasticity	E	210 Gpa

Table 3: Specifications Of Concrete Used In The Subway Tunnel

Cylindral 28-Day Strength	f_{ck}	**52 Mpa**
Poisson Coefficient	**V**	**0.2**
Elastic Modulus	E	**40Gpa**
Density	**ρ**	**2500($kg/m3$)**

The Model Consists Of Two Main Parts: The Tunnel And The Earthen Environment. To Simulate Earthquake Conditions In This Research, A Sinusoidal Displacement Function With A Maximum Amplitude Of 30 Cm And A Periodicity Of 1.8 Seconds Was Applied To The Entire Model In The Direction Perpendicular To The Longitudinal Axis Of The Tunnel. The Displacement Component Of The Beginning And End Of The Tunnel Is Also Bounded In The Longitudinal Direction Of The Tunnel.

Figures 4, 5 And 6 Respectively Show The Boundary Conditions Of The Model, The Boundary Conditions At The Beginning And End Of The Tunnel, And The Definition Of Loading And Suitable Boundary Conditions In The Load Module. In The Last Step, The Whole Model Is Meshed. It Should Be Noted That The Type Of Element Used To Cover The Shell Element Tunnel Is S4R, And The Soil Mass Is C3D8R. Figures 7 And 8 Respectively Illustrate The Soil Mass Meshing And Tunnel Meshing.

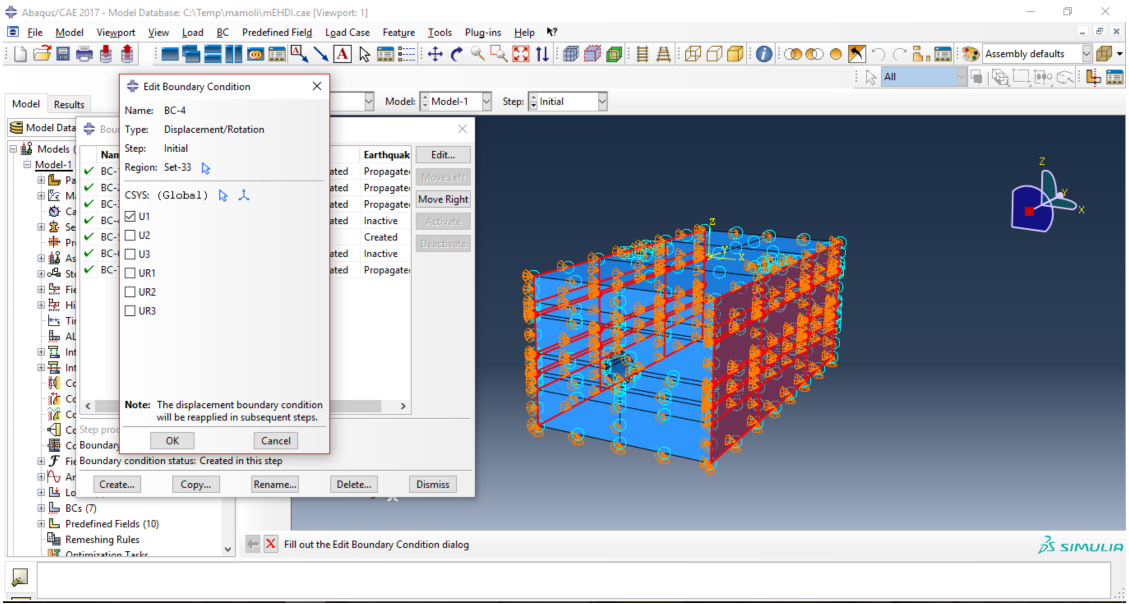

Figure 4: Model Boundary Conditions

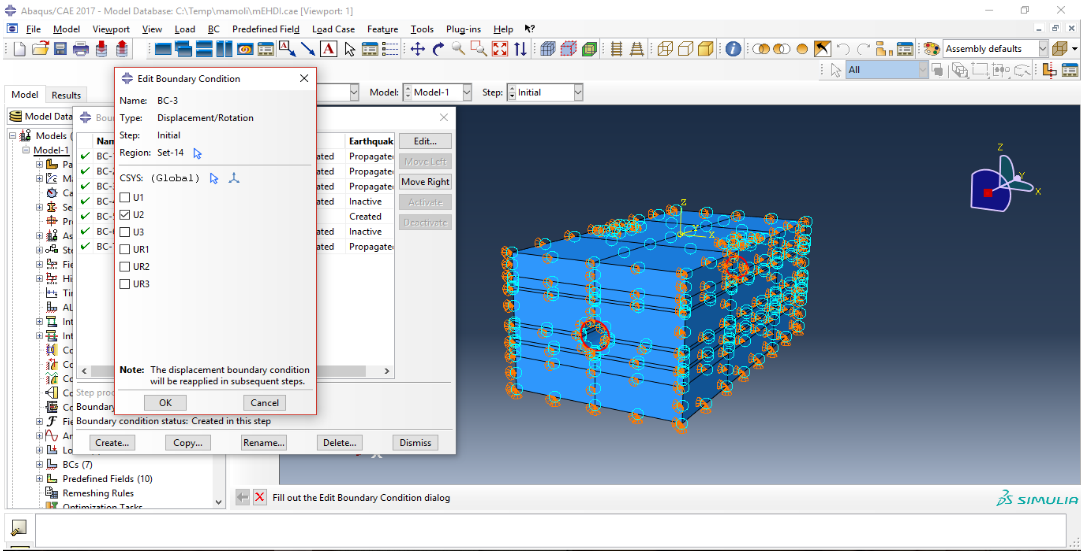

Figure 5: Boundary Conditions At The Beginning And End Of The Tunnel

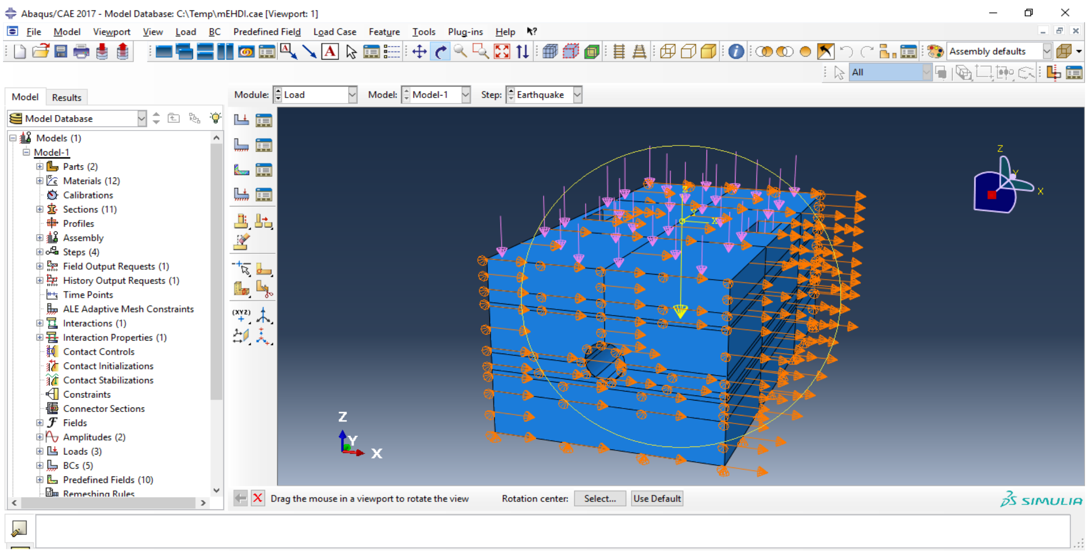

Figure 6: Definition Of Loading And Appropriate Boundary Conditions In The Load Module

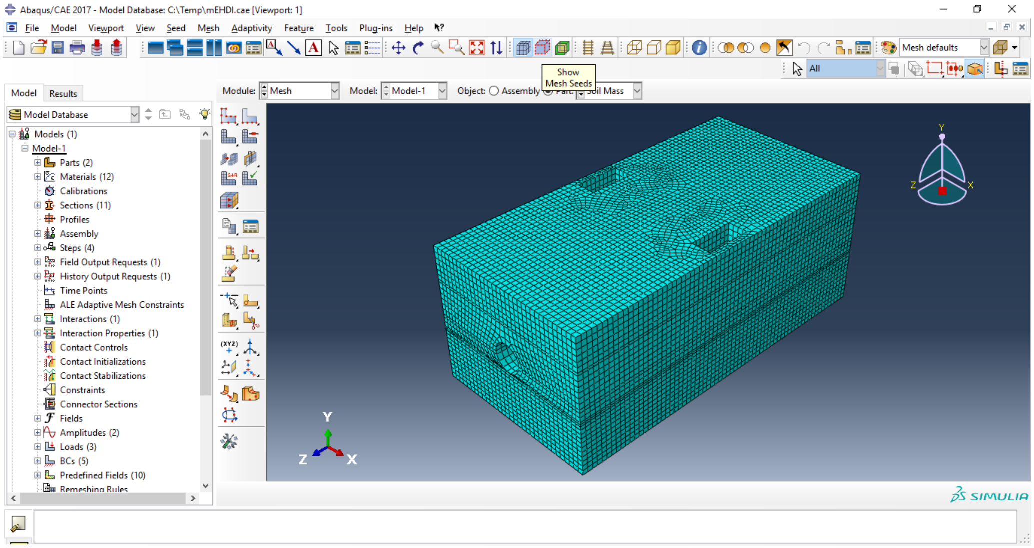

Figure 7: Soil Mass Meshing

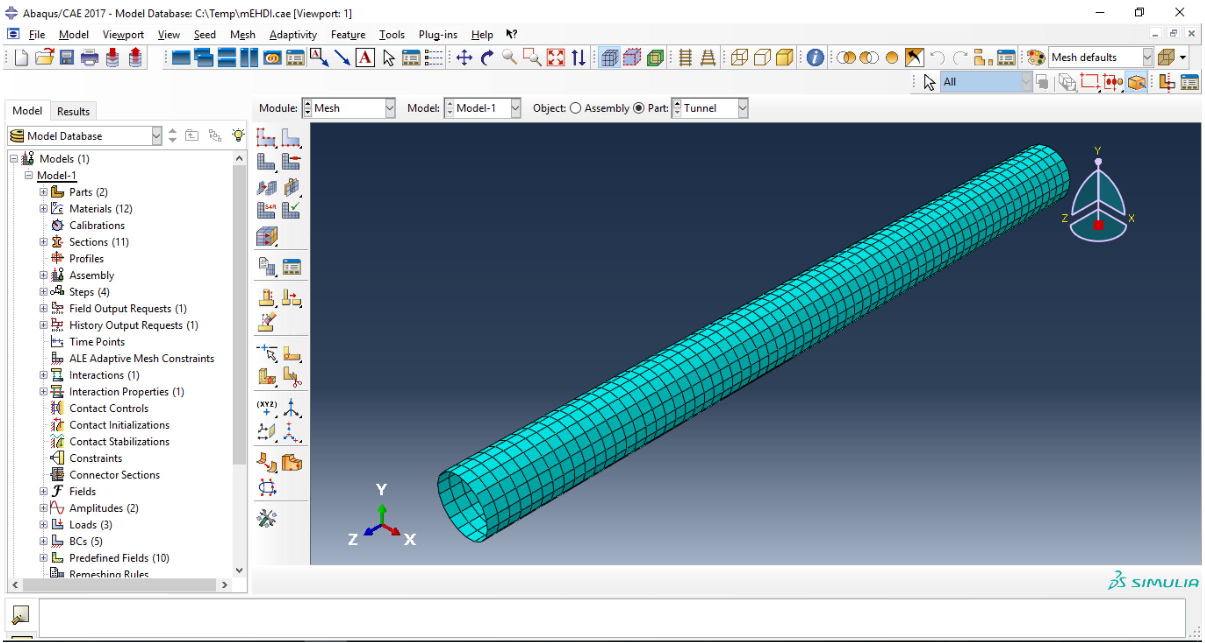

Figure 8: Tunnel Meshing

Analysis Of Findings From Modeling

In Steps One And Two, The Amount Of Strain Generated In The Critical Section Is Insignificant, And This Is Due To The High Modulus Of Elasticity And Shear Modulus Of Concrete With Fly Ash. But In The Third Step, The Strain Values Increase Owing To The Seismic Loading. The Same Is True For Stress. Also, Compared To The Concrete With Fly Ash And The Concrete Used In Tunnels, The Amount Of Stress And Strain Has Decreased In All Three Steps, Indicating The High Ductility And Strength Of Concrete With Fly Ash. Moreover, Reducing The Stress And Strain On The Concrete Reduces The Amount Of Stress On The Reinforcing Linings, Leading To Reduced Rebar Reinforcement Required For The Concrete Section. Figure 9 Shows The Displacement In The X-Direction Under Gravity Load.

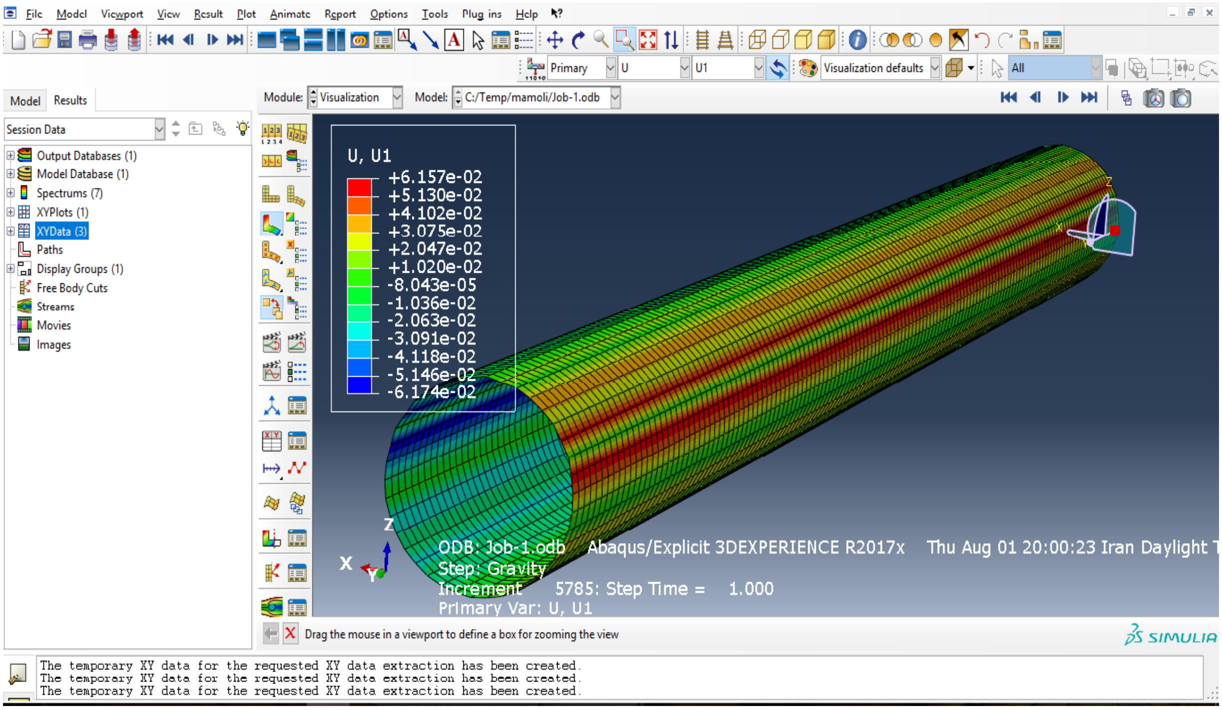

Figure 9: X-Direction Displacement Under Gravity Load

The Authors Further Examined Acceleration Under Gravity Load, Acceleration Under Dead Load, Acceleration Under Earthquake Load, Strain In X-Direction Under Gravity Load, Strain In Y Direction Under Gravity Load, Strain In Z Direction Under Gravity Load, Strain In X-Direction Under Dead Load, Strain In Y Direction Under Dead Load, Strain In Z Direction Under Dead Load, Strain In X-Direction Under Earthquake Load, Strain In Y Direction Under Earthquake Load, And Strain In Z Direction Under Earthquake Load.

Review Of Analyzed Models With Software

Figures 10 To 12 Plot The Diagrams Of The Displacement Of Concrete Sections In The Subway With Concrete With Fly Ash In Different Loading Steps, Indicating The Adequacy Of The Designed Section. The Numbers 1, 2 And 3 Represent The X, Y And Z Axes, Respectively.

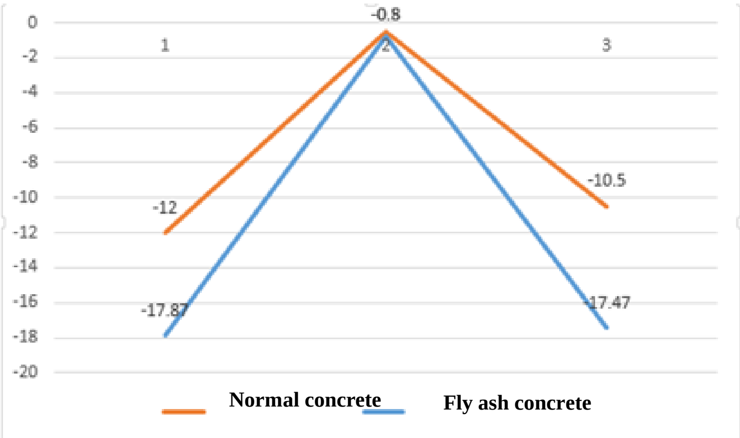

Figure 10: Comparison Of The Displacement Of Concrete Sections In The Subway With Concrete With Fly Ash In The Gravity Step

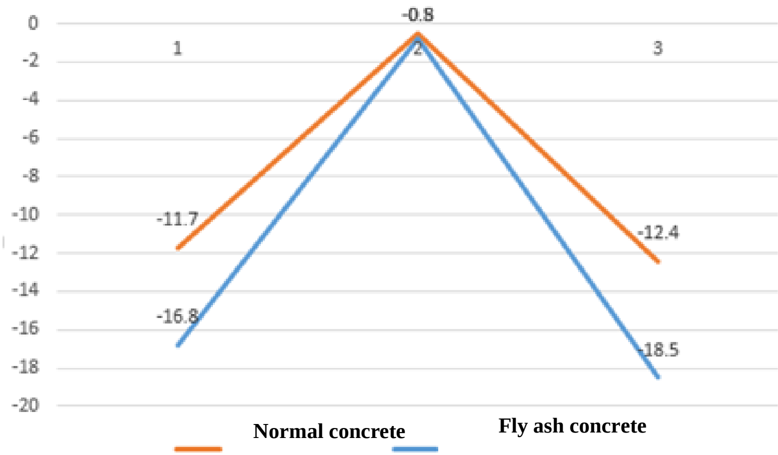

Figure 11: Comparison Of The Displacement Of Concrete Sections In The Subway With Concrete With Fly Ash In Dead Load Step

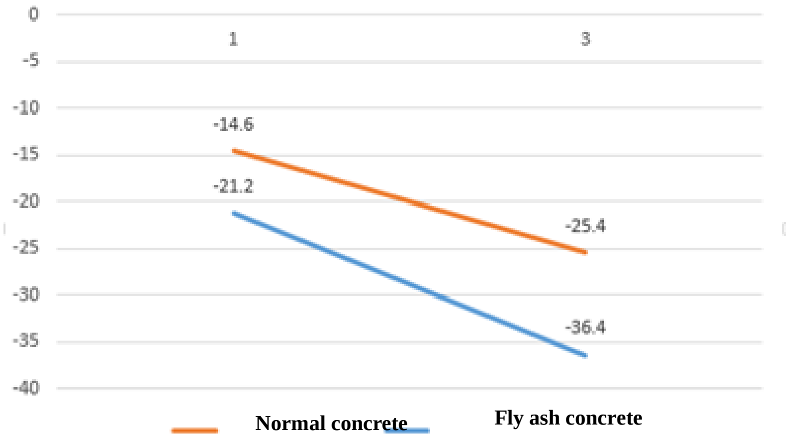

Figure 12: Comparison Of Displacement Of Concrete Sections In The Subway In Two Directions, X And Z, With Concrete With Fly Ash In Earthquake Load Step

According To The Above Diagrams, The Displacement Values In The X Direction Have Decreased By 5 To 6 Cm At Different Loading Steps. The Displacement Values In The Z Direction Show A Decrease Of 6 To 7 Cm In The Gravity And Dead Load Steps And 11 Cm In The Seismic Loading Steps, Indicating A 25 To 35% Reduction In The Displacement Of Concrete With Fly Ash Compared To Conventional Concrete Of The Subway Tunnel In Different Directions And At Different Loading Steps.

The Displacement Values In The Y Direction, Firstly, In Both Cases, Are Very Small Compared To The Other Two Directions. Secondly, There Is A Negligible Difference Between The Two States. The Above Statement Can Be Stated That The Y Direction Is In The Longitudinal Direction Of The Tunnel. Earthquake Load Also Enters The Tunnel Perpendicular To This Direction, Which Causes Insignificant

Displacement Values In This Direction.

Adequacy Of Concrete Section And Changes In Its Dimensions

Examinations Indicate That The Concrete Used In The Tabriz City Train Project Has A Compressive Strength Of 35 Mpa And A Modulus Of Elasticity Of 30 Mpa And Has Been Deployed With A Thickness Of 35 Cm. Also, According To The Test Results, It Was Found That The Compressive Strength Of Concrete With Fly Ash Is 52 Mpa And Its Modulus Of Elasticity Is Close To 40 Mpa.

The Authors Sought To Examine The Behavior Of The Concrete By Reducing The Thickness Of The Concrete Shell Using Trial And Error. This Reduction Was Done First By 25 Cm And Then By 20 Cm Since Reducing The Thickness Of The Concrete Shell From 25 Cm Led To A Sudden Deformation And Strain. Therefore, The Minimum Shell Thickness Was Considered To Be 25 Cm. Figure 13 Shows The Displacement Changes To Compare The Thickness Of The Concrete Shell.

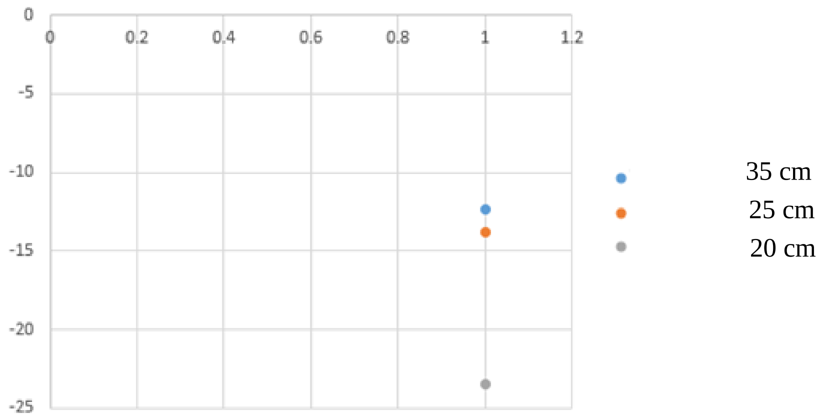

Figure 13: Changes In Displacement For Comparing The Thickness Of Concrete Shells

Conclusion

The Findings Indicated That The Concrete Samples Of The Variant With The Water/Cement Ratio Of 0.45 And Fly Ash/Cement Ratio Of 15% Exhibited Maximum Strength. As Such, This Variant Was Used For The Research

By Inputting The Geotechnical Properties Of The Area Soil Obtained From The Drilled Boreholes, The Metro Tunnel Was Modeled With An Area Of 50 M X 100 M. Hence, The Properties Of The Concrete With Fly Ash And Concrete Used In The Tunnel Lining Of The Subway Were Inputted Into The Software. Following The Analysis Of The Model, Outputs Such As Stress, Strain And Displacement Were Obtained For Both Modes. The Maximum Displacement Values Before The Earthquake Were 12.4 Cm In The Vertical Direction For Concrete With Fly Ash And 18.4 Cm For The Already Deployed Concrete. After The Earthquake, These Values Were 25.4 Cm And 36.4 Cm, Respectively. Also, The Displacement Values In The X Direction Have Decreased By 5 To 6 Cm At Different Loading Steps. The Displacement Values In The Z Direction Show A Decrease Of 6 To 7 Cm In The Gravity And Dead Load Steps And 11 Cm In The Seismic Loading Steps. Finally, The Study Of Cross-Sectional Displacements For Both Concretes Showed That Concrete With Fly Ash Exhibited Better Performance With Less Thickness Under

The Same Conditions.

Since The Thickness Of The Concrete Section Of This Project Is A Mere Estimation And Not A Known Parameter, The Maximum Outputs Obtained Were Shown In Diagrams And Tables. To Control The Adequacy Of The Section With A Thickness Of 25 Cm, The Sensitivity Of Outputs Was Examined By Trial And Error And Reducing The Thickness In The Software. The Reinforcement Grid Was Examined By Arranging 15 10M Rebars Out Of Every 6 Cm And 15 12M Rebars Out Of Every 6 Cm For The Case Of 25 Cm Thickness. The Change Effect In Rebar Thickness Was Negligible. The Adequacy Of The Metal Section For The Period Of Operation Mentioned In The Structural Design Report Of Metro Line 2, With 14 10M Rebars Of Every 6 Cm, Is Appropriate.

According to the Results, The Author Suggests the Design Of Hollow And Cubiax Shells And Roofs With Fly Ash Concrete And The Design Of Traverse Train Tracks With Fly Ash Concrete.

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