



“**SEGMENTAL BOX PUSHING TECHNIQUE:**

 **RELATED PROBLEMS AND SOLUTION**”

**(MAJOR - I)**

 A dissertation submitted in partial fulfillment of the

requirement for award of the degree of

MASTER OF TECHNOLOGY

In

CIVIL ENGINEERING

With specialization in

STRUCTURAL ENGINEERING

 BY

 **Y S CHAUDHARY**

 Enroll No: 2K11/STR/18

 Under guidance of

Dr. Narinder Dev, Professor

 Department of Civil & Environmental Engineering

 Delhi Technological University, Delhi 110042

**CERTIFICATE**

This is to certify that the project entitled “SEGMENTAL BOX PUSHING TECHNIQUE: RELATED PROBLEMS AND SOLUTION” being submitted by me is a bonafied record of my own work carried out by me under the guidance and supervision of Dr. Narinder Dev, Professor in partial fulfillment of requirement for the award of the degree of Master of Engineering (Civil Engineering), with specialization in Structural Engineering, from Delhi Technological University, Delhi.

The matter embodied in this project has not been submitted for the award of any other degree.

 **Y S Chaudhary**

Enrollment No: 2K11/STR/18

This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

|  |  |
| --- | --- |
| **Dr. Narinder Dev**ProfessorDelhi Technological UniversityDelhi |  |

Acknowledgement

I wish to express my deep sense of gratitude and appreciation to Dr. Narinder Dev, Professor for their guidance and valuable advice throughout this project, without which completion of this project would not have been possible.

I also express my sincere gratitude to the faculty of Civil Engineering Department, Computer Centre & Library, Delhi Technological University, Delhi. I also would like to express my appreciation to many sources, including those specially mentioned in the references, at the end of the text for using their literature for preparation of this report. I express special thanks to Dr. Sanjeev Kumar Garg, IRSE and Mr. Shiv Om Dwivedi, IRSE for their endless support, whenever I faced problem.

I also express special thanks to my wife Mrs. S. Chaudhary and my daughter Annu Chaudhary for their co-operation and support during this work.

Last but not the least, I am thankful to my colleague and friends for their forbearance patience, encouragement and guidance.

**Y S CHAUDHARY**

**LIST OF CONTENTS**

|  |  |  |
| --- | --- | --- |
|  1. | **Introduction**  | **1-21** |
|  | 1.0 | Preamble | 1 |
|  | 1.1 | Methods of Road Under Bridge Construction | 1 |
|  | 1.2 | Historical development of box pushing | 2 |
|  |  | 1.2.1 | Indian Scenario about box pushing | 4 |
|  | 1.3 | Introduction to box pushing technique | 5 |
|  |  | 1.3.1 | Design of box | 5 |
|  |  | 1.3.2 | Segmental construction | 5 |
|  |  | 1.3.3 | Design of thrust bed | 5 |
|  |  | 1.3.4 | Front cutting shield & rear jacking shield | 7 |
|  |  | 1.3.5 | Hydraulic equipment for jack units | 7 |
|  |  | 1.3.6 | Progress of pushing | 7 |
|  |  | 1.3.7 | Reduction of frictional resistance | 9 |
|  |  | 1.3.8 | Quality control | 9 |
|  |  | 1.3.9 | Line & level control | 10 |
|  |  | 1.3.10 | Completion period | 10 |
|  | 1.4 | Survey of problems in Segmental box pushing | 10 |
|  |  | 1.4.1 | Misalignment of box | 11 |
|  |  | 1.4.2 | Ground disturbance | 11 |
|  |  | 1.4.3 | Collapse of tunnel face | 11 |
|  |  | 1.4.4 | Failure of thrust bed | 13 |
|  |  | 1.4.5 | Failure of jacking station | 13 |
|  |  | 1.4.6 | Failure of anti-drag system | 15 |
|  |  | 1.4.7 | Presence of high water | 15 |
|  | 1.5 | Summary of survey | 17 |
|  | 1.6 | Problem statement | 17 |
|  | 1.7 | Importance of study | 19 |
|  | 1.8 | Aims and Objective of Study | 20 |
|  | 1.9 | Organization of report | 20 |
| 2.0 | Literature Review | 22-37 |
|  | 2.0 | Preamble | 22 |
|  | 2.1 | Temporary and permanent works element | 22 |
|  |  | 2.1.1 | Docklands light Railway, Lewisham, London | 23 |
|  |  | 2.1.2 | Silver Street Railway Station London | 25 |
|  |  | 2.1.3 | MI Motorway, Junction 15 A Northamtonshire | 25 |
|  |  | 2.1.4 | Tunnel Box construction Boston South Railway Station | 28 |
|  |  | 2.1.5 | Flood relief culvert, Dorney | 31 |
|  |  | 2.1.6 | Large jacked Tunnel in Shanghai using steel pipe screen support | 32 |
|  |  | 2.1.7 | Concrete box culvert, South west point of Fort Worth, Texas | 33 |
|  |  | 2.1.8 | Lothian masonry Arch Bridge (Near old Delhi Railway) | 35 |
|  |  | 2.1.9 | Road under Bridge (RUB) by Tube Heading Technique at Bidhan Nagar Railway Station, Calcutta | 35 |
|  |  | 2.1.10 | Subway in Indian Institute of Science, Bangalore | 36 |
|  | 2.2 | Assessment of ability to adopt improvements for tunnel stability in box technique based on Literature Review | 37 |
|  | 2.3 | Direction for the present study | 37 |
| 3.0 | **Failure analysis and discussion** | **38-45** |
|  | 3.0 | Preamble | 38 |
|  | 3.1 | Causes of failure of tunnel face | 38 |
|  | 3.2 | Mechanism of Failure | 38 |
|  | 3.3 | Slope stability Analysis using Stability Number Method | 40 |
|  |  | 3.3.1 | Procedure for analysis | 41 |
|  |  | 3.3.2 | Case study for analysis | 42 |
|  |  |  | 3.3.2.1 Extension of cutting edge | 43 |
|  |  |  | 3.3.2.2 Slope stability Analysis | 44 |
|  | 3.4 | Major observation of analysis | 45 |
| 4.0 | **Soil Nailing Application in Box Pushing Technique** | **46-58** |
|  | 4.0 | Preamble | 46 |
|  | 4.1 | Introduction of soil nailing | 46 |
|  | 4.2 | Background | 47 |
|  | 4.3 | Application and Feasibility Evaluation | 47 |
|  |  | 4.3.1 | Suitable in situ ground conditions | 48 |
|  |  | 4.3.2 | Soil condition not conducive for soil nailing  | 48 |
|  | 4.4 | Types of soil nail | 48 |
|  |  | 4.4.1 | Grouted nails | 49 |
|  |  | 4.4.2 | Driven nails | 49 |
|  | 4.5 | Construction material for soil nailing | 50 |
|  |  | 4.5.1 | Reinforcement bar (nail or tendon) | 50 |
|  |  | 4.5.2 | Nail head | 50 |
|  |  | 4.5.3 | Grout | 50 |
|  |  | 4.5.4 | Centralizers | 51 |
|  |  | 4.5.5 | Facing | 51 |
|  | 4.6 | Soil Investigation | 51 |
|  | 4.7 | Construction sequence | 52 |
|  | 4.8 | Nail pullout testing | 56 |
|  |  | 4.8.1 | Equipment for testing | 56 |
|  | 4.9 | Advantages of soil nailing | 58 |
| 5.0 | **Design of soil Nailing** | **59-75** |
|  | 5.0 | Preamble | 59 |
|  | 5.1 | Initial design considerations | 59 |
|  |  | 5.1.1 | Wall layout | 59 |
|  |  | 5.1.2 | Soil nail vertical and horizontal spacing | 59 |
|  |  | 5.1.3 | Soil nail pattern on wall face | 59 |
|  |  | 5.1.4 | Soil nail length and distribution | 59 |
|  | 5.2 | Other Design consideration | 60 |
|  |  | 5.2.1 | Loads and load Combitions | 60 |
|  |  | 5.2.2 | Permissible soil wall Deformations | 60 |
|  |  | 5.2.3 | Drainage Measure | 61 |
|  |  |  | 5.2.3.1 Short term drainage measures | 61 |
|  |  |  | 5.2.3.2 Long term drainage measures | 61 |
|  |  | 5.2.4 | Corrosion protection | 61 |
|  |  |  | 5.2.4.1 Corrosion protection measures | 62 |
|  |  | 5.2.5 | Field pullout test | 62 |
|  |  | 5.2.6 | Verification test | 62 |
|  |  | 5.2.7 | Creep Test | 63 |
|  | 5.3 | Geotechnical Investigation | 63 |
|  |  | 5.3.1 | Bulk Density | 63 |
|  |  | 5.3.2 | Natural water Content | 64 |
|  |  | 5.3.3 | Specific Gravity | 64 |
|  |  | 5.3.4 | Atterberg’s Limits | 65 |
|  |  |  | 5.3.4.1 Liquid Limit | 65 |
|  |  |  | 5.3.4.2 Plastic limit | 67 |
|  |  |  | 5.3.4.3 Plasticity Index | 67 |
|  |  | 5.3.5 | Soil Classification | 67 |
|  |  | 5.3.6 | Direct Shear Test | 69 |
|  | 5.4 | Case Study for design calculation based on design charts | 69 |
|  |  | 5.4.1 | Design calculations for driven nails | 70 |
|  |  | 5.4.2 | Design calculations for Grouted nails | 72 |
| 6.0 | **Model Study Related to Box Pushing** | **76-83** |
|  | 6.0 | Preamble | 76 |
|  | 6.1 | Choice of model size | 76 |
|  |  | 6.1.1 | Description of model for experimental study | 76 |
|  |  | 6.1.2 | Set up for pull out test | 76 |
|  | 6.2 | Soil Nailing | 77 |
|  |  | 6.2.1 | Reinforcing bars | 77 |
|  |  | 6.2.2 | Spacing of cells | 77 |
|  |  | 6.2.3 | Pattern of nailing | 77 |
|  |  |  | 6.2.3.1 Unreinforced soil | 77 |
|  |  |  | 6.2.3.2 Uniform soil nail pattern | 77 |
|  |  |  | 6.2.3.3 Staggered soil nail pattern | 77 |
|  |  |  | 6.2.3.4 Grouted nails | 77 |
|  |  | 6.2.4 | Soil nailing inclination | 79 |
|  |  | 6.2.5 | Soil nail length and distribution | 79 |
|  |  | 6.2.6 | Application of nails | 79 |
|  |  | 6.2.7 | Grouted nails | 79 |
|  | 6.3 | Instrumentation and observations | 79 |
|  | 6.4 | Load applications | 79 |
|  |  | 6.4.1 | Desired loading for experiment | 81 |
|  |  |  | 6.4.1.1 Track structures | 81 |
|  |  |  | 6.4.1.2 Ballast | 82 |
|  |  |  | 6.4.1.3 UDL from earth cushion | 82 |
|  | 6.5 | Calculation of design load for pullout test | 82 |
|  |  | 6.5.1 | Data for design | 82 |
|  |  | 6.5.2 | Design for driven nails | 83 |
|  |  | 6.5.3 | Design for grouted nails | 83 |
|  | 6.6 |  | Observation for experiment | 83 |
| 7.0 | **Results and Discussion** | **84-92** |
|  | 7.1 | Geothermal Properties of Soil | 84 |
|  |  | 7.1.1 | Geotechnical properties of soil | 84 |
|  |  | 7.1.2 | Shear parameters | 85 |
|  | 7.2 | Pullout resistance test | 86 |
|  | 7.3 | Results of model study | 86 |
|  |  | 7.3.1 | Lateral deformation of soil face | 87 |
|  |  | 7.3.2 | Inference of observations from Fig. 7.1 | 88 |
|  |  | 7.3.3 | Inference of observations from Fig.7.2 and 7.3 | 88 |
| 8.0 | **Conclusion and recommendations for further studies** | **93-94** |
|  | 8.1 | Conclusions | 93 |
|  | 8.2 | Recommendations for further studies | 94 |
| 9.0 | **Reference** | **95-97** |

**LIST OF FIGURES**

|  |  |  |
| --- | --- | --- |
| Figure 1.1 | Construction of RUB by Segmental Box Pushing | 6 |
| Figure 1.2 | Fixing of Front cutting shield | 8 |
| Figure 1.3 | Power Pack | 8 |
| Figure 1.4 | Distribution of pushing load | 8 |
| Figure 1.5 | Intermediate jacking stations (I.J.S.) | 8 |
| Figure 1.6 | Jack application at jacking pin | 8 |
| Figure 1.7 | Horizontal misalignment | 12 |
| Figure 1.8 | Vertical misalignment | 12 |
| Figure 1.9 | Disturbance to track parameter | 12 |
| Figure 1.10 | Disturbances to soil mass | 12 |
| Figure 1.11 | Slippage of soil bank | 12 |
| Figure 1.12 | Collapse of tunnel face | 12 |
| Figure 1.13 | Cutting edge (exit end) | 14 |
| Figure 1.14 | Plan of Thrust Bed | 14 |
| Figure 1.15 | Jacking pins | 14 |
| Figure 1.16 | Failure of Jacking pins | 14 |
| Figure 1.17 | Improper Jacking Station | 14 |
| Figure 1.18 | Failure of Jacking station | 14 |
| Figure 1.19 | Frame for fixing sheets | 16 |
| Figure 1.20 | Plan showing fixing of sheets | 16 |
| Figure 1.21 | Hangers for sheets | 16 |
| Figure 1.22 | Box ready for installation | 16 |
| Figure 1.23 | Box partially installed | 16 |
| Figure 1.24 | Box fully installed | 16 |
| Figure 1.25 | Slope in concrete face of leading segment | 18 |
| Figure 1.26 | Cutting shield divided in small rectangles faces | 18 |
| Figure 1.27 | Placement of light steel beams | 18 |
| Figure 1.28 | Placement of light steel beams | 18 |
| Figure 1.29 | Sand bags near excavation face | 18 |
| Figure 1.30 | Sand bags on embankment | 18 |
| Figure 2.1 | Docklands Light Railway, Lewisham, London | 24 |
| Figure 2.2 | RUB at Silver street Railway Station, London  | 26 |
| Figure 2.3 | Cellular shield with steel plated cutting edges exposed at end of tunneling, MI motorway, Northamtonshire | 26 |
| Figure 2.4 | Major features of the Scheme of Tunnel jacking operation | 30 |
| Figure 2.5 | Ground Freezing In Progress | 30 |
| Figure 2.6 | Special cutting shield (steel grid) | 34 |
| Figure 2.7 | Arrangement of pipe screen | 34 |
| Figure 2.8 | Special joint for pipe screen | 34 |
| Figure 2.9 | Slurry piping & rebar in box walls | 34 |
| Figure 2.10 | Steel casing pipe for guidance | 34 |
| Figure 2.11 | Guided pushing | 34 |
| Figure 3.1 | Bore holes & thrust bed location | 39 |
| Figure 3.2 | Soil Stability diagram | 39 |
| Figure 3.3 | Stability charts for soils with friction angle | 40 |
| Figure 3.4 | Vehicular box (9.25 x 5.0m) | 43 |
| Figure 3.5 | Drainage box (2.0 x 2.0m) | 43 |
| Figure 4.1 | Main components of a typical soil nail | 49 |
| Figure 4.2 | Typical sequence of construction for a soil nailed structure | 43 |
| Figure 4.3 | Shotcrete temporary facing | 55 |
| Figure 4.4 | Temporary facing for grouted nails | 55 |
| Figure 4.5 | Temporary facing, using removable steel plates | 55 |
| Figure 4.6 | Temporary facing using gunny bags | 55 |
| Figure 4.7 | Removal of temporary facing for driving nails | 55 |
| Figure 4.8 | Completion of soil nailing sequence | 55 |
| Figure 4.9 | Soil nail load testing setup | 57 |
| Figure 4.10 | Hydraulic jack used for soil nail load testing | 57 |
| Figure 5.1 | Flow curve:Variation of no. of blows with moisture contents | 66 |
| Figure 5.2 | Particle size distribution curve | 68 |
| Figure 5.3 | Modified Davis design chart | 70 |
| Figure 5.4 | Normalized bond strength for Batter 0 o  -Back slope 0 o | 72 |
| Figure 5.5 | Correction factors | 73 |
| Figure 6.1 | Typical sequence of experimental set up | 78 |
| Figure 6.2 | Driving of nails | 80 |
| Figure 6.3 | Open hole auger drilling | 80 |
| Figure 6.4 | Dial gauge fixing for observation of deformation  | 80 |
| Figure 6.5 | Pullout test of sacrificial nail | 80 |
| Figure 6.6 | Load application | 80 |
| Figure 7.1 | Variation of deformation with surcharge load | 90 |
| Figure 7.2 | Variation of deformation ratio with surcharge load | 91 |
| Figure 7.3 | Deformation ratio for different patterns of nails at maximum surcharge loading | 92 |

**LIST OF TABLES**

|  |  |  |
| --- | --- | --- |
| Table 1.1 | Summary of large box structures installed in a wide variety of ground conditions | 3 |
| Table 3.1 | Value of bulk density, natural moisture content and dry density | 42 |
| Table 3.2 | Value of c & 0 throughout the explored depth | 42 |
| Table 3.3 | Stability slope angle *i* | 45 |
| Table 7.1 | Sieve analysis of soil sample | 84 |
| Table 7.2 | Geotechnical properties of soil | 85 |
| Table 7.3 | Pullout test of soil nailing for driven nails | 86 |
| Table 7.4 | Pullout test of soil nailing for grouted nails | 86 |
| Table 7.5 | Variation of lateral deformation of soil mass | 87 |
| Table 7.6 | Variation of deformation ratio | 87 |

**ABBREVIATIONS**

|  |  |
| --- | --- |
| ADS | Anti-drag Sheet |
| ANSB | Anand Vihar |
| DLI | Delhi |
| GA | General arrangement |
| FHWA | Federal Highway Administration |
| GI | Galvanized iron |
| GZB | Ghaziabad |
| HYSD | High yielding steel deformed |
| I.J.S | Intermediate jacking station |
| IRC | Indian Road Congress |
| IRS | Indian Railway Specifications |
| MS | Mild steel |
| RUB | Road under Bridge |
| ROB | Road over Bridge |
| RCC | Reinforced cement concrete |
| UK | United Kingdom |
| US | United States |
| m | Meter |
| mm | Millimeter |
| Cm | Centimeter  |

**SYMBOLS**

|  |  |
| --- | --- |
| Ø | Angle of internal friction of soil |
| ᵧd | Dry density of soil |
| c | Cohesion of soil |
| Sn | Stability number |
| F | Factor of safety |
| δn | Effective normal stress on the failure plane of soil |
| Ød | Developed angle og internal friction of soil |
| cd | Developed Cohesion of soil |
| i | Stable soil slope angle |
| v | Angle of cutting edge with vertical |
| ᵧ | Bulk density |
| qu | Ultimate bond strength |
| µ | Normalized bond strength |
| CIL | Correction factor for drill hole diameter (Nail Length) |
| CIF | Correction factor for drill hole diameter (Force) |
| DDH | Drill hole diameter |
| fy | Yield strength of concrete |
| Fst | Factor of safety for nail bar strength |
| Fp | Factor of safety for pullout resistence |
| SH | Horizontal Spacing |
| Sv | Vertical Spacing |

**ABSTRACT**

 This herein project, aims at presenting the solution for tunnel face stability in Box Pushing projects. Present day Intensity of Traffic, both Rail & Road, due to the fast development of Industries and other Infrastructures, is very heavy and so it cannot be disturbed, for construction of RUB or Canal Crossings, drainage conduit etc by conventional method i.e. open cut system. In order to avoid the inconvenience and disruption of traffic associated with traditional cut and cover method, Box Pushing (also called Jacket Box Tunnel) technique is developed, to construct RUB, where in R.C.C. boxes are cast in segments outside and pushed through the heavy embankments of rail or road by heavy jacking. The required thrust to push the segments is generated through thrust bed. Line and levels of pre-cast boxes during pushing are controlled by thrust bed.

 Construction of RUB by segmental box pushing is a non intrusive technique for construction of under bridges beneath existing surface infrastructure such as railways or highways. This method is being used by Indian Railways for constructing RUB for last few decades but it has gained importance recently due to heavy infrastructure growth leading to a number of road infrastructure projects. At present, the work is being done in diverse conditions and during execution of work in the field; various problems are being faced by the site engineers.

 This project aims at presenting the Box Pushing technique, comprehensively, in addition to the discussion on problems being encountered during execution and their probable causes. Efforts have also been made to propose solution for the most critical practical problem of tunnel face stability by performing Field Model Study to predict the behavior of the suggested solution in a specific structure under working conditions. The concept of soil nailing is proposed to be used for the stability of tunnel face during box pushing operations. The fundamental concept of soil nailing consists of reinforcing the ground by closely spaced passive inclusion to create insitu coherent gravity structure, and thereby increase the overall shear strength of the insitu soil and restrain its displacement on loading. A small scale model (proportionate to the dimensions of box size) is chosen for experimental study of evaluation of soil nailing technique.

CHEPTER 9

**REFERENCES**

|  |  |
| --- | --- |
| 9.1 | Carlos A. Lazarte, Ph.D., P.E., Victor Elias, P.E., R.David Espinoza, Ph.D., P.E., Paul J. Sabatini, Ph.D., P.E. FHWA (2003) – Geotechnical Engineering Circular No.7;- Soil Nail Walls Report No.FHWA0-IF-03-017. |
| 9.2. | Civil Engineering & Construction Review:- Tunnels and tunneling (September, 1992) “Box Jacking Technique-Cemindia widens Delhi Road Underbridge”, A compilation of Reprints from CE & CR (1992-98), 129, Somdutt chambers-II, 9, Bhikaji Cama Place, New Delhi, pp 20 to 23. |
| 9.3 | Ge, J.k., (2005) – New tunnel construction technique of pipe-roof method in saturated soft soil, A.A. Balkema Publisher Underground Space Use: Analysis of the Past and Lessons for the Future – Erdem & Solak (eds) © 2005 Taylor & Francis Group, London, ISBN 04 1537 452 9, pp-365 to 369 |
| 9.4 | Geo-technical investigation report (2007) – Proposed construction of RCC box at Km.8/14-15 for replacement of level crossing no 156 on Delhi-Shahibabad section at Vivek Vihar, New Delhi, Project reference 07060647 – Explore Engineering Consultants Private Limited, D-154, Basement, Sector-61, Noida. |
| 9.5 | Gunaratne, Manjriker (2006)- The Foundation engineering Hand Book – CRC Press Taylor & Francis Group 6000 Broken Sound Parkway NW, Suite 300 Boca Ration, London-pp 487 to 500. |
| 9.6 | IRC-3200-IRC publication “specifications for soil nailing work”, [www.grogle.com](http://www.grogle.com). |
| 9.7 | Indian Railway Permanent Manual (1986), Ministry of Railways, Railway Board, Government of India. |
| 9.8 | Indian Railway Standard, IRS Code of Practice for design of bridges and structures, Volume – I & II, 2004, issued by Research Design and standard Organisation, Lucknow. |
| 9.9 | IS: 2720 (Part 4)-1985: (1986), Reaffirmed 2006, “Methods of Test for Soils: Part-2, Determination of Grain Size Analysis”, Bureau of Indian Standards. |
| 9.10 | IS: 2720 (Part VII) – 1980 (2003), Reaffirmed 2003, “Methods of Test for Soils: Part-7, Determination of Water Content Dry Density Relation using Light Compaction”, Bureau of Indian Standards. |
| 9.11 | IS:2720 (Part III/Sec I) – 1980. (1980) – Reaffirmed 2002, “Methods of Test for Soils: Part-3, Determination of Specific Gravity, Fine Grained Soils”, Bureau of Indian Standards. |
| 9.12 | Indian Express Newspaper (Bombay) Ltd., (19.08.2000) – IISc scientists build subway using unique technique www.grogle.com.  |
| 9.13 | International Railway Course, (2008): Study material provided during a course conducted by East Japan Railway Culture Foundation at Shinshirakawa, Japan from 19 Feb.2008 to 13 March 2008. |
| 9.14 | Jha, Ramesh Kumar & Sarkar, Rupak, (1996) – Road under Bridge (RUB) by Tube Heading Technique at Bidan Nagar Railway Station Calcutta – Proceeding of 3rd National seminar on Planning & Management of Bridges & Flyovers by Delhi State Centre in May 1996 – pp 323 to 331. |
| 9.15 | Lynn, Anthony, (2006) – Box-jacking – a useful construction tool – 4th International Engineering and Construction Conference – July 28, 2006, Berkeley Engineering Company, Inc. |
| 9.16 | Ropkins, J.W.T., (1998) – Jacked box tunnel design and construction – Journal of Transportation Engineering, Vol. 109, Nd. 1, January, 1983 – ASCE (ed), Proceedings of the Sessions of Geo-Congress 98, Special Publication No 87, Boston, 1998, Boston: ASCE. |
| 9.17 | Ropkins , J.W.T., and Attenby , D., (2005) – Jacked box tunneling, a non-intrusive technique for constructing under bridges, A.A. Balkema Publisher Underground Space Use: Analysis of the Past and Lessons for the Future – Erdem & Solak (eds) © 2005 Taylor & Francis Group, London, ISBN 04 1537 452 9, pp 443 to 447.  |
| 9.18 | Punmia, B.C, Jain, Ashok Kumar, Jain, Arun Kumar (2005) – Soil mechanics and Foundations – Luxmi Publications (P) Ltd.  |
| 9.19 | Srivastava, S.K., (1996) – Design consideration in Bank failures during Box pushing – Proceeding of 3rd National seminar on Planning & Management of Bridges & Flyovers by Delhi State Centre in May 1996 – pp 239 to 244. |
| 9.20 | Shimizu,M., Watanabe, A., Nishijima, K., Kurisu, M., Kuwabara, K., Genjun, T. & Arakawa, E., (2005) – New method of underground structures using multi elements which are jointed with the specific junctions, A.A. Balkema Publisher Underground Space Use: Analysis of the Past and Lessons for the Future – Erdem & Solak (eds) © 2005 Taylor & Francis Group, London, ISBN 04 1537 452 9, pp 497 to 502  |
| 9.21 | ShivakumarBabu. G.L. (2006) – Soil reinforcement and Geosynthetics, University Press (India) Private Limited, Hyderabad., pp 118 to 133. |
| 9.22 | Special report no 16 (1996) – State of the art : Reinforced soil structures applicable to road design and construction – IRC Highway research Board, New Delhi. |
| 9.23 | Talwani, Rajesh, : The Fort Worth experience and auger Boring Machine used to Jack Concrete Box Culture under Rail road-www.google.com |
| 9.24 | Taylor, Steve & Pennicem, Derek (2001) – Jacking large tunnel beneath active rail tracks in Hatch mott macdonald, -177 Milk Street, Boston, MAO 2109. |
| 9.25 | The Institution of Engineers, India – Tirupati and the local unit of Indian Geotechnical Society organized, :- Contribution of top engineer recalled, the 10th memorial lecture of Late Engineer T. Narayana Reddy at SVU Senate Hall on Thursday (Online edition of India’s national paper – The Hindu, Monday, Dec 01, 2008). |