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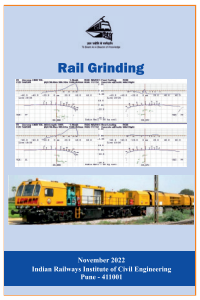
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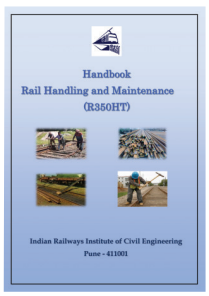
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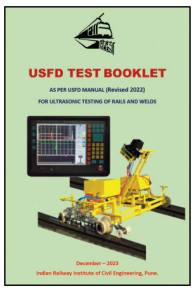


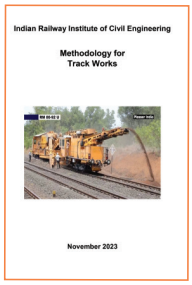




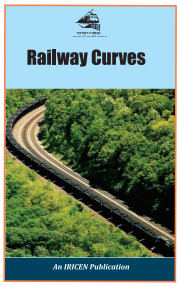


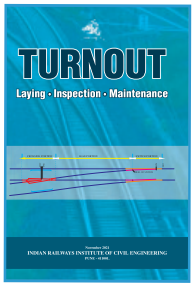


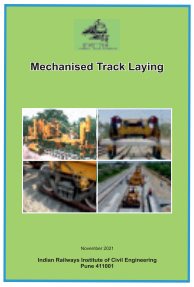




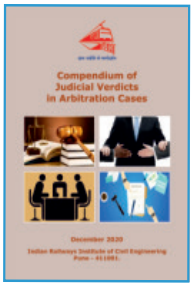


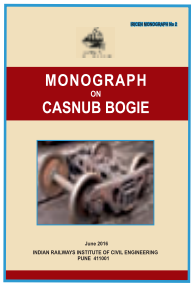


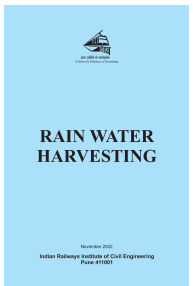


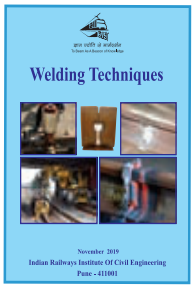


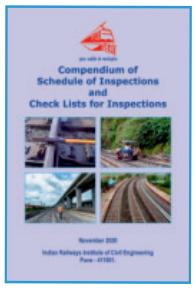


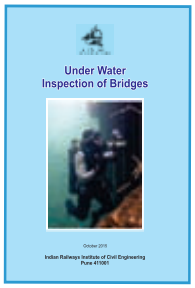


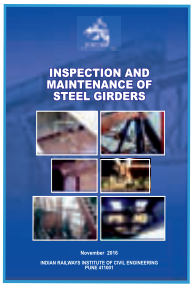


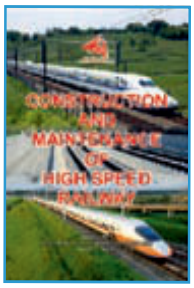


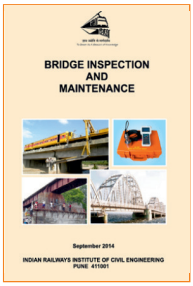




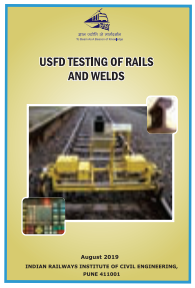


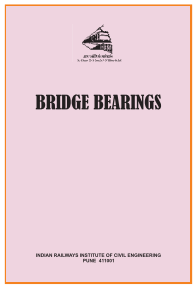


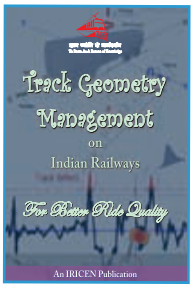




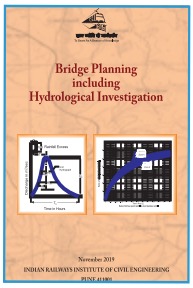


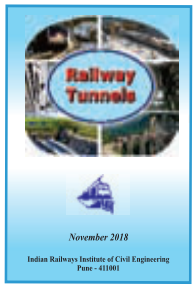


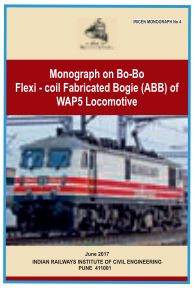


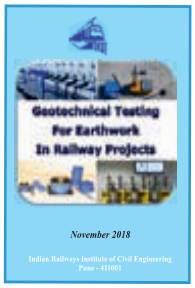


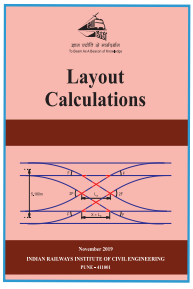


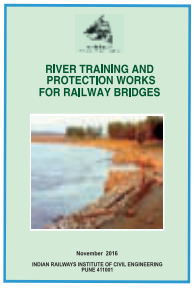


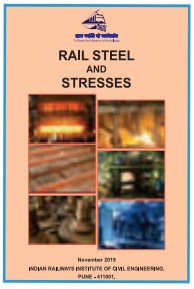


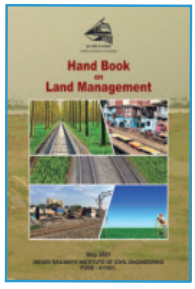


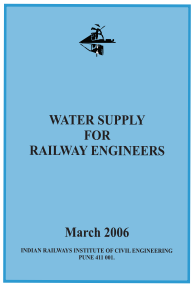


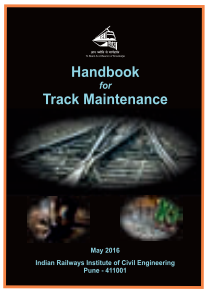














From Director General's Desk

Dear Readers,

Railway fraternity has shown great enthusiasm to bring out this December issue. Papers have been included in diverse topics. The first technical paper is "INNOVATION: Prevention of sagging of tracks at the approaches of Railway Culverts and Bridges". Another paper is A Study on Ground Improvement by using Geogrid and Non-Woven Geotextile Layers at Metro Car Depot at Joka.

The third paper deals with skew slab bridges for railway loadings. There is also a paper on Stability equations for embankment design.

I sincerely hope that readers would find the papers and other articles contained in this journal informative and useful. The suggestions for making this journal more useful and relevant to the field user and the contribution for forthcoming issues in the form of technical papers are welcome. This will help in sharing their knowledge and experience with the Railway Engineers.

Pune
December 2023

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Director General

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1. The paper may be a review of conventional technology, possibilities of improvement in the technology or any other item which may be of interest to the readers. The paper should be reasonably detailed so that it could help the reader to understand the topic. The paper may contain analysis, design, construction, maintenance of railway civil engineering assets. The paper should be concise.
2. The journal is likely to be printed in a paper of size 215 mm X 280 mm. While sending the articles the author should write in 2 columns. Sketches, tables and figures should be accommodated in a 2 column set up only.
3. Author should send the original printout of photograph along with the digital copy of the photograph.
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5. Only selected articles will be included in the IRICEN Journal of Civil Engineering.

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Plans for trans-Persian Gulf railway emerge at G20 Summit



A new commitment to develop an economic corridor from India to the Middle East and Europe, centred on a transcontinental railway and seaway running through the Persian Gulf to Israel, was announced during the G20 summit in Delhi, India, on September 9. Heralded by the United States President, Mr Joe Biden, as a "big deal," the "landmark corridor" is expected to stimulate economic development by providing enhanced connectivity and economic integration across two continents. Biden was joined in signing the MoU by the leaders of the European Union (EU), France, Germany, Italy, India, Saudi Arabia, and the United Arab Emirates (UAE). The Memorandum of Understanding (MoU) states that the India-Middle East- Europe Economic Corridor (IMEC) will consist of an eastern corridor, connecting India to the Persian Gulf, and a northern corridor connecting the Persian Gulf to Europe. The resulting cross-border railway/ seaway will enable goods to move between India, the UAE, Saudi Arabia, Jordan, Israel and Europe. The project will also include the installation of new electricity and digital communications interconnections and a hydrogen pipeline along the entire length of the new railway corridor. The MoU states that the participants commit to meet within the next 60 days to develop and agree an action plan with relevant timescales for delivery. No funding commitments have yet been made for the project. The signing took place during a special side event held at the G20 Summit on September 9. The railway further details are currently scarce. Logically, the new corridor would use the recently-completed Etihad Rail network in the UAE, which stretches from Fujairah Port in the northeast of the country, via Dubai and Abu Dhabi, to Al Ghuweifat on the border with Saudi Arabia. There is currently a gap in the rail network here, but providing Saudi Arabia delivers on its plans to extend its network from Haradh to Al Batha and ultimately the rail head at Ghuweifat as part of the wider Gulf Cooperation Council (GCC) railway project, the corridor could make use of the Saudi Arabia Railways (SAR) network, including the 2750km North-South Railway to the Jordanian border at Al Qurayat. From here, further new construction across Jordan would be required. A possible cross-border route would run to Beit Shean, the current eastern terminus of Israel's rail network, which provides a direct link to the northern port city of Haifa. The recently announced Connecting Israel programme to construct 300km of new railway throughout the country includes plans to reactivate the cross-border line to Jordan via this route.The US is thought to favour the initiative as a means of countering China's growing influence in the region, while the EU's involvement is central to its efforts to deepen trade and investment links with the Gulf region. Under its Global Gateway Project, the EU has earmarked €300bn for spending on global infrastructure projects, also as a counter to China's Belt and Road Initiative (BRI).

Ref. : International Railway Journal (Oct. 2023)

(Extract)

Indian Cabinet Approves Multitracking Projects

Cabinet Committee on Economic Affairs chaired by Prime Minister, Mr Narendra Modi, has approved projects worth a total of Rs 325bn ($US 3.19bn) to lay additional tracks on seven sections of the Indian Railways' (IR) network. The government says it will provide 100% of the funding for the projects being taken forward by the Ministry of Railways, which aim to reduce congestion and ease train operation on the busiest sections of the IR network. The projects are:

- Gorakhpur - Cantt – Valmiki Nagar: doubling of existing line
- Son Nagar - Andal: multitracking
- Nergundi - Barang and Khurda Road - Vizianagaram: third track
- Mudkhed - Medchal and Mahbubnagar - Dhone: doubling of existing line
- Guntur - Bibinagar: doubling of existing line
- Chopan - Chunar: doubling of existing line, and
- Samakhiali - Gandhidham:quadrupling.

Project completion will increase the total length of the IR network by 2339 track-km. Providing additional capacity is expected to result in an additional 200 million tonnes of freight traffic a year for IR, helping India to meet its climate change goals.

Ref. : IRJ October 2023

India's Eastern Dedicated Freight Corridor completed

Commercial operation began on India's completed 1337km Eastern Dedicated Freight Corridor (EDFC) on November 1. After a decade and a half of construction, the completion of the entire EDFC connecting Ludhiana in Punjab to Sonnagar in Bihar was announced by Dedicated Freight Corridor (DFC) managing director, Mr R K Jain. The estimated cost of the World Bank-funded EDFC is Rs 550bn ($US 6.6bn The EDFC has capacity for up to 250 trains a day, and will largely cater for coal traffic, serving the thermal power plants in the states of Uttar Pradesh, Punjab, Haryana and Rajasthan. The line will reduce the transit time for freight between Ludhiana and Sonnagar from 35-50 hours on existing main lines to 18-20 hours. The EDFC is initially expected to carry 153 million tonnes of freight, rising to 251 million tonnes by 2036-37. The 1506km Western Dedicated Freight Corridor (WDFC), funded by the Japan International Cooperation Agency (Jica) and connecting Dadri in Uttar Pradesh to Jawaharlal Nehru Port in Navi Mumbai, is still under construction and due to be completed early next year. On October 30, Indian Prime

Minister, Mr Narendra Modi, inaugurated the 77km New Bhandu - New Sanad section in Gujarat. Both the EDFC and WDFC have missed several completion deadlines, leading to an estimated 54% escalation in costs. In March last year, railways minister, Mr Adhwani Vaishnaw, announced plans to build the East Coast Corridor, East-West sub corridor and the North South Corridor, but IR is now considering alternatives such as adding additional tracks to existing lines, which is likely to be a more costeffective and faster option.

Ref. : IRJ October 2023

India - Bangladesh cross-border line reopens

THE 12.24km link connecting Agartala, India, with Akhoura, Bangladesh, has reopened for the first time since the Partition of India in 1947. The cross-border project was inaugurated by Indian Prime Minister, Mr Narendra Modi, and his Bangladeshi counterpart, Ms Sheikh Hasina, on November 1. The link comprises a 6.78km dual 1676mm and 1000mm-gauge section in Bangladesh and a 5.46km broad-gauge section in the Indian state of Tripura. The new line via Bangladesh will reduce the distance by rail between Kolkata in West Bengal and India's seven northeastern states from 1600km to 500km, cutting journey times by 22 hours. Bangladesh has authorised the Indian government to move freight from the ports of Chattogram and Mongla in Bangladesh to West Bengal and the northeastern states.

Funding for the project was included in India's 2012-13 rail budget, increasing from an initial Rs 3.9bn ($US 46.8m) to Rs 12.6bn. Links to Mongla, the second largest port in Bangladesh, have been improved by the opening of a 65km broad-gauge line from Khulna in Bangladesh, built at a cost of $US 388.9m with financial support from the Indian government.

Ref. : IRJ December 2023

Indian Railways unveils new 130km/h long-distance EMUs for low-cost market

INDIAN Railways (IR) has unveiled a variant of the Vande Bharat EMU targeting the lowincome passenger market. The new 22-car Vande Sadharan (Vande Ordinary) has capacity for a total of 1800 passengers, with 18 unreserved and four reserved non-airconditioned coaches. The maximum speed is 130km/h, lower than the 160km/h Vande Bharat.

While each Vande Bharat train costs Rs 1.2bn ($US 14.6m), the Vande Sadharan reportedly costs Rs 600m. The new train has a 4.4MW power car at each end, manufactured at a cost of Rs. 280m at Chittaranjan Locomotive Works (CLW) and moved to the Chennai-based Integral Coach Factory (ICF) to be formed into trains with German-designed LHB coaches.

Two Vande Sadharan trains arrived at Mumbai's Wadi Bunder yard on October 29 for trials on the 169km Mumbai - Nashik corridor, with a particular emphasis on performance over hilly terrain. Commercial operation is likely to begin on the New Delhi - Mumbai route. Additional Vande Sadharan trains are expected to be introduced depending on demand, IR officials said.

Compared with conventional passenger trains currently in operation, the Vande Sadharan will have improved interiors and amenities including automatic doors, bio-toilets and modern radio communications systems. The cost per seat of the Vande Sadharan would be 25% less than fares for the premier Vande Bharat trains. However, they are not equipped with airconditioning, which has been criticised

Ref. : IRJ December 2023

Trans Mash Holding and Rail Vikas Nigam Ltd have signed a agreement

Trans Mash Holding (TMH) and Rail Vikas Nigam Ltd (RVNL) have signed a 75:25 agreement to set up the Kinet Railway Solutions joint venture, which will supply and maintain Vande Bharat EMUs for Indian Railways (IR). TMH and RVNL will manufacture 120, 16-car long-distance EMUs for IR at the Marathwada Rail Coach Factory in the city of Latour, Maharashtra.

Ref. : IRJ September 2023

India issues high-speed fleet tender

INDIA's National High Speed Rail Corporation (NHSRCL) has issued a tender worth an estimated Rs 110bn ($US 1.33bn) for the supply of 24 E5 series Shinkansen trains for the under-construction Mumbai - Ahmedabad highspeed line. NHSRCL plans to use the first batch of the 10-car trains to conduct trials on a 50km section of the new railway between Surat and Bilimoria in Gujarat state in 2026. Each train will have capacity for 690 passengers. According to the terms of the Japanese International Cooperation Agency (JICA) funding agreement for the high-speed project, only Japanese firms can submit bids for the rolling stock contracts. Hitachi Rail and Kawasaki Heavy Industries, which built the E5 for East Japan Railway (JR East), are therefore considered the front runners to win the contract. Bids are expected to be submitted by the end of October. The winning bidder will also be responsible for building rolling stock maintenance depots at Sabarmati and Thane.

"It will take one year to finalise the designs of the trains, keeping in mind the specific geographical conditions in India," says an official associated with the project. "The first two Shinkansen trains are expected to arrive by 2025."

Ref. : IRJ August 2023

Prevention of Sagging of Tracks at the Approaches of Railway Culverts and Bridges

P. K. Samanta Roy[1]

[1] *CE (Con –III)/SECR/BSP*

ABSTRACT

Now a days, sections are opened for traffic immediately after construction of new bridges for opening a new line, doubling, tripling etc. However, it is seen that during the rainfall of next monsoon, the bridge approaches get sagged to a large extent at both the ends. This gives heavy jerks to the running trains endangering safety. As a result, speed restrictions are imposed for a considerable period of time. Such cases have been viewed as a natural corollary of new bridge construction with no solution in sight.

This project critically examines the processes involved in the construction of bridge approaches in order to find out the probable solution. As per the stipulations contained in the Bridge Manual and Bridge Sub-structure code, based on which all the bridges are constructed, the bridge approaches have to be filled up to a width of 600 mm with well hand packed boulders and cobbles followed by suitable backfill materials behind them. During new bridge construction in Kalmitar-Salka Road section of Bilaspur Division of SECR, it was found that if the boulder layers are packed with the backfill materials in such a way that there won't be any void left among them for the backfill particles to migrate, the sagging could be controlled to a large extent. This innovative finding was further refined by using sand in place of the usual backfill material for packing the boulders which yielded much better results by way of practically no sagging of bridge approaches in Bridge No.19 Down recently constructed in the Kalmitar-Salka Road section. It has also been proposed to further improve the system by fixing of Stainless steel meshes of specified pore sizes to stop escape of any amount of sand from the bridge approaches through the weep holes of the return wall / abutment. This will enable us to construct bridges with no problem of sagging at all over its entire life.

This will tremendously help railways to ensure better safety and saving of at least Rs.68 lakhs per annum per bridge by doing away with the need of imposing speed restrictions and consequent better utilization of railway assets. This innovative method has to be adopted all over Indian Railways for the benefit of all. Suitable modification in the Bridge Manual and Bridge Substructure Code may be initiated to this end.

Introduction

The entire Indian Railway network has 127768 numbers of bridges including major and minor ones and out of this 1208 bridges are rebuilt in the year 2007-2008. Apart from this a number of new bridges are being made year after year as part of expansion of the existing railway network.

A recurring problem associated with the opening of a new bridge is sagging of the approaches of the abutment and Box culvert, which is a serious safety hazard. This entails imposition of speed restriction for variable period of time at a heavy cost of detentions and poor utilization of railway assets. This condition entails special attention of the bridge approaches thereby inflating the maintenance cost as well. This project attempts to critically analyze the present system of building bridges so as to identify the reasons for the problem and suggest possible solutions. This is based on the experiences gained during construction of new bridges in the Kalmitar-Salka Road section of Bilaspur division of SECR.



As per Para 605 of Bridge Manual of Indian Railways,1998 (Annexure 1) and Para 7.5.1 of Bridge Sub- structure Code,2003 (Annexure 2), the approach of abutment of a bridge or Box Culvert has to be filled by well hand packed Boulders/ Cobbles to a width of 600 mm (minimum) and backfill materials behind them. The same is endorsed vide RDSO Drg/M/00004/1-2 dated 21-04-05(Annexure 3). All the bridges in Indian railways are built as per stipulations given in the above codes and manuals. However, the sagging of the bridge approach is seen in all of them. This is particularly manifested during rainy season. Last year, ME/ Railway Board has ordered that the newly constructed bridges have to be opened for traffic at maximum permissible speed immediately with out waiting for the monsoons to be over. This makes it imperative that a solution for the sagging has to be found out as soon as possible.

The boulders packed in the bridge approaches contain voids by virtue of their shapes and the back fill materials packed behind them migrate to occupy these voids facilitated by rains. This eventually causes the settling down of the approaches causing sagging. To prevent such migration of the backfill material from behind the boulders, the innovative methods used are aimed at filling up the voids themselves so that there is no space available for such migration. Before going to the details of these methods it is pertinent to make an analysis of the present system in detail.



2. Present system:

Presently, all the new bridges are constructed following the stipulations given in Para 605 of Bridge Manual, Para 7.5.1 of Bridge Sub- structure Code and RDSO Drg/M/00004/1-2 dated 21-04-05. The approach of abutment of bridge has to be filled by well hand packed Boulders and Cobbles for a width of 600 mm (minimum) with smaller size towards the back. Behind the Boulder filling, backfill materials shall consist of GW, GP, SW groups as per IS: 1498-1970 as per the above references. The same is adopted in case of Box culvert also. So, the entire approach is filled by boulders with cobbles and backfill materials up to the top of the Box Culvert and then blanketing materials are filled up to the level and +25mm above the designed formation level, if the designed formation level is higher than the top of the culvert or abutment of bridges. The bridges are constructed simultaneously with laying of formation using blanketing materials or otherwise as per site conditions. Later on, compaction of the formation is achieved by using vibrating rollers of 12 Tones capacity. In case of opening of a new line, doubling or tripling etc., the new bridges constructed are opened in the same year without waiting for monsoon to pass. These processes are made clear by giving a representative figure, which demarcates the different constituents of a bridge.

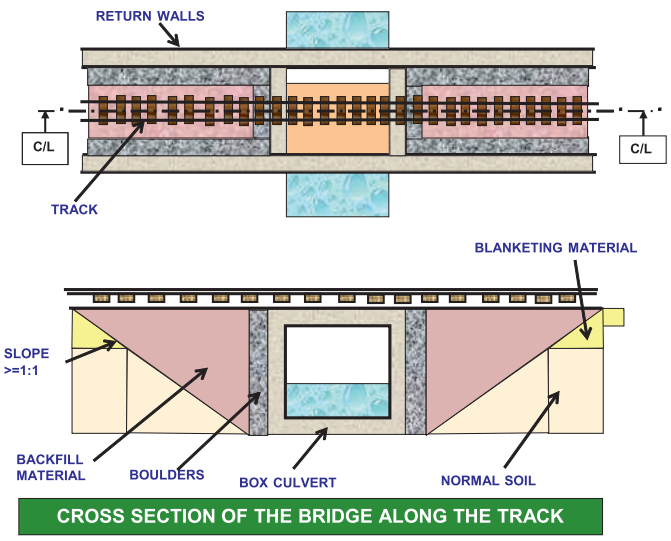


Fig.1. Newly built bridge as per the present system

So, in the present system, up to 600mm of the abutment of the bridges or box culverts boulders are packed. However, by virtue of the size and shapes of the boulders, there are some spaces left among them, which can be occupied by the backfill materials from behind in due course aided by the normal settling process. This is expedited in case of heavy rains. These materials can easily enter into the voids of "hand packed boulders and cobbles". The position becomes worst when it rains. The backfill materials get entrapped in the voids, leaving their original place where it was supporting ballast cushion under the load of sleeper and rails and the bridge approaches get sagged to a great extent depending upon the height of embankment on bridge approaches as



shown below in the figure 2 because the bridge is a non-compressible structure with deformed approaches on both sides.

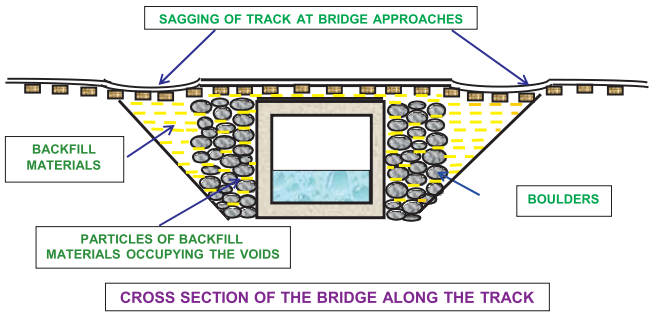


Fig.2. Sagging of bridge approaches due to migration of back fill materials

The new bridges are now a days opened with a speed of 80 Kmph on the day one and recently Member Engineering has given directives to open the section with the maximum permissible speed of the section, i.e., in case of group "D" route 100 Kmph. The sagging of the bridge takes place within 3-4 days of the rains and this gives massive jerk to the running trains moving at high speed with serious safety hazards. As a result, speed restrictions are required to be imposed and continuous maintenance attention by way of packing with excess ballast and extra manpower deployment has to be carried out. The sag formed on approaches becomes a "pocket" where more rainwater gets collected and further deterioration of formation takes place. Due to continuous packing for re-leveling, depth of ballast cushion also increases beyond the standard 350mm height resulting in unstable track causing deterioration of "Ride Index". This is the main contributory factor for bad running over most of the bridge approaches constructed earlier.



Photograph showing sagging of approach and excess ballast cushion :

As the root cause of the problem of sagging was traced back to the migration of backfill particles from beneath the approaches, the possible means of stopping this was thought of. The innovative idea of packing the boulders with backfill materials or any other suitable cost-effective material was tried out successfully in a total of 11 bridges in Kalmitar - Salka Road section of Bilaspur division. The details of the processes adopted are discussed now.

Proposed systems:

Process – 1

Step (1) Packing of boulders and backfill materials in layers :

At the time of construction of bridges, the voids of boulders have to be filled with the existing backfill materials conforming to GW, GP, SW. groups as per IS- 1498- 1970. In this process, one layer of boulders is laid over a width of 600mm & voids are filled with the same backfill materials at the same time. The backfill materials are laid up to the boulder layer and packing of the backfill materials inside the voids of the boulders is done with pokers. The "Ponding Technique" follows this where water is poured over the backfill material laid over the boulders to collect as if in a pond followed by continuous poking till the water disappears. Likewise, all the voids among the boulders were filled with the backfill materials. Behind the boulder layer the backfill materials are filled and compacted till it reaches the level of the boulder layer. This process is continued layer after layer till we reach the top of the box culvert or the abutment.

Step (2) Consolidation of the approaches:

The above process will be continued till the top of boulder filled with back fill material reaches up to the top of the Box Culvert and then blanketing materials are filled up to the level +25mm to +50mm above the designed formation level, if the designed formation level is higher than the top of the culvert. The reason for keeping the approach of bridge level a little higher than the designed formation level is to avoid sagging of formation level in any case, so that even after a little settlement of formation, there will not be sag. However, because it is not possible to compact the layers using 12 Tones vibratory rollers (Diameter of roller is 1.5m), compaction has to be achieved in stages by carrying out manual compaction.

This technique has to be adopted on both the approaches of bridges as well as in side of return wall / wing wall.

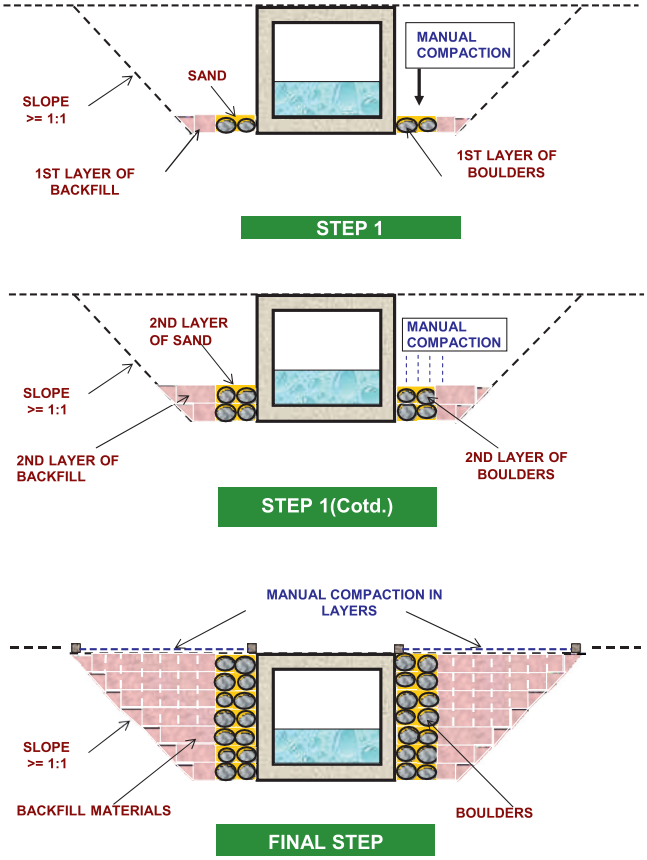


Fig.3. CROSS SECTION OF THE BRIDGE ALONG THE TRACK

Advantages:

- The above innovation has been successfully implemented in Bridge numbers 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 up in Kalmitar-SalkaRoad section with no instance of speed restrictions being imposed even after passage of two monsoons after opening . It has been observed that this process is also effective for non ballasted track bridges having spans 12.2m or above, where specially designed approach slabs have to be provided, to prevent creation of vacuum under the approach slab as a result of migration of particles of back fill material towards existing voids in the hand packed boulders & cobbles. Hence, the above innovative technique will help to provide uniform level track at bridge approaches without any need of speed restriction & ensure safe running of trains. The photograph below clearly indicates uniform level of cess, toe line of ballast and uniform level of track. The photograph below was taken during rainy season and it can be seen that there was no sagging in the track and to endorse this, no speed restriction board was also visible at the site.



Photograph of Bridge No. 16 showing level track :

Process- 2

To make process more effective, alternate materials for packing the boulders were thought of so that no amount of backfill material can migrate from the approaches. Well-Graded sand has been found to be more effective than the usual standard backfill materials used. Here all the steps followed in the Process one will be followed. This technique has been adopted in the construction of Bridge No. 19 Dn in the Kalmitar-Salka Road section. There is practically no sagging even after 3 months of its opening and despite having heavy downpour during this period. However, on close observation it is found that very small quantity of sand particles were escaping with the oozing water through the weep holes of the Box culvert. This may over a period of time result in slight sagging. Therefore, improving the above process further so that there will not be any chance of sagging during the lifetime of the bridge was thought. This has given rise to further innovative idea, which is depicted in the next process.



However, there are reported cases of slight sagging of less than 6mm over a chord length of 7.5m, which do not necessitate the imposition of speed restrictions. So, it is thought to further innovate to make the process more effective.

Process-3

Fixing of Stainless steel Wire meshes inside the weep holes:

With the process No.2, there was no sagging observed, but it was noticed that the sand filled among the boulders were coming out of the weep holes in small quantity during the rainy season. In course of time, this may also cause voids equivalent to its volume. To completely eliminate the problem of displacement of sand particles from the intended locations, specially prepared filters made of stainless steel mesh of 16 SWG, with 49 holes per sq cm. is proposed to be fitted at the back side face of abutment, Return wall or Wing wall at the location of weep holes. This is represented in the following figure.

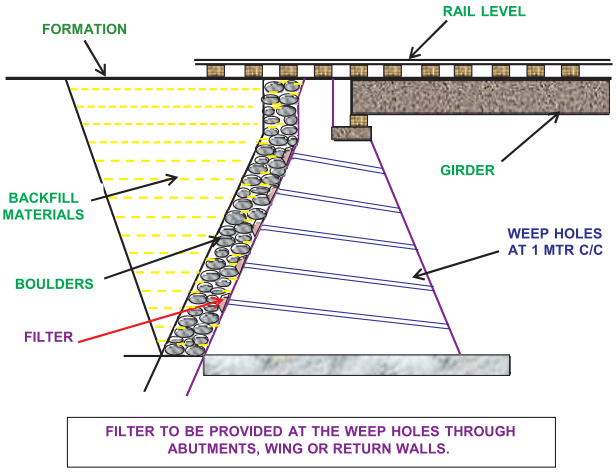


Fig.4. Fixing of stainless steel wire mesh filters at the weep holes

Advantages :

By adopting the innovations given in the process 3 we will be able to achieve an all weather solution to the problem of sagging of bridge approaches till the end of the life of the bridge. The process 3, has been introduced in Bridge no. 19 Dn, by externally placing the stainless steel wire mesh from outside through the weep holes.s noticed in the Br. that above innovation is permitting, oozing of only water without any sign of escape of, either sand or backfill material's fine particles. This innovation is highly beneficial to Railway's in terms of monetary benefit as well as safety of running train hence its adoption is absolutely necessary.

Cost-Benefits Analysis

Costs Involved:

(A) Cost of sand: Cost for an average bridge (3 mt span and 10 mt barrel length) @ 0.28 cum sand per cum of hand packed boulder comes to be approximately Rs 4620 per bridge. It is calculated as:

Volume of sand required	= 0.28xvol.of boulders
	= 0.28 x (7+10+7) x2x0.6x3
	= 24.19 cum
Rate of sand	= Rs.191 per cum
Cost of sand required	**=24.19 x 191**
	= Rs 4620

(B) Cost of stainless steel wire mesh: 36 pieces of stainless steel wire mesh cut out of 1 sqm costing Rs 210/-. Hence, cost per wire mesh is Rs 210/36. Total stainless steel wire mesh required on an average bridge

(Bridge no. 16 of 3.66m span) with 48 weep holes. Hence,

cost = [48X(210/36)]= Rs 280.

PROPOSED TOTAL EXPENCES = 4620+ 280 =**Rs. 4900/-**

Quantitative Savings / Benefits:

1. *Savings of Detention of trains:*

   Considering an average section having 10 Coaching trains and 15 Goods trains daily over a bridge with speed restriction of 30 Kmph due to sagging of track at the approaches during rainy season the following calculation is being made. Each train is thus loosing about 2.5 to 3.5 minutes running time while passing the bridge. The normal speed of Coaching trains is 100 Kmph and that of Goods trains is 75 Kmph. Per Km cost of hauling of a Coaching train is Rs. 534.44 and that of a Goods train is Rs. 809.71 (Ref : Annual Statistical statements 2007-08 of Indian Railways, page 145& 148). Therefore, in case there is no speed restriction on the bridge, net saving comes to Rs. 0.75 lakhs per day, i.e. Rs. 67.88 lakhs for 3 months of the rainy season per bridge.

Table.1 : Time lost and the cost in observing caution for coaching and goods trains

Year	Total no. of bridges	No. of bridges rehabilitated or rebuilt*
2007-08	127768	1208
2006-07	127768	1114
2005-06	127768	1431
2004-05	121295	1579
2003-04	119984	1563

1	2	3	4
Type of train	Normal speed	Avg. no. of trains running per day in the section	Avg. loss in running time
Coaching	100 Kmph	10	2.5 Min.
Goods	75 Kmph	15	3.5 Min.

5	6	7	8	9
Proportionate Km. loss per train	Total Km. Loss per day over a bridge approach	Avg. Km. Cost of hauling per train (in Rs.)	Saving in cost per bridge per day (in Rs.)	Saving in cost per bridge for 3 months (in Rs.)
100*2.5/60 = 4.17	4.17*10 =41.7	534.44	41.7*534.44 =22286.15	22286.15*90 = 20,05,753.50
75*3.5/60 =4.375	4.375*15 =65.625	809.71	65.625*809.71 = 53137.22	53137.22*90 = 47,82,349.70
TOTAL			75,423.37	67,88,103.20

In addition to new lines, doubling, tripling etc. this improvised process of formation of track at the bridge approaches may be adopted in case of rehabilitation or rebuilt of Railway bridges, which are also substantial in number as may be seen from the following table:

*Ref : Indian Railways Year Books.

2. Saving of Cost of Speed Restriction Boards: for imposition of speed restriction, we require a total of boards : One Warning Board, One Speed board and Two Termination boards. The cost of the Warning Board comes to Rs. 2140; speed board comes to 1940 and two TP & TG boards comes to 4000. The values given are as per the prevailing estimated rates at Bilaspur Division Construction Organization. Total MS angles required for erection of the caution boards comes to be 60kg. The cost of MS angle per kg comes to 38.50. So, the cost of 60 kg MS Angle comes to Rs. 2310. Adding all the above figures the total cost of the Boards comes to Rs.10390.

3. Saving of cost of TRACK BALLAST : There is saving in track ballast required to pack under the sleepers, equivalent to quantum of sag, to keep the track level.

   Prevailing rate of ballast on cess= Rs. 645/- per cum

   Quantity = 24.19 cum (Equivalent to Qty. of sand) Cost of ballast saved = Rs. 24.19x 645/- =Rs. 15603/-

   GROSS TOTAL SAVING = 67,88,103 + 10390 + 15603

   = 68,14,096/-

   NET SAVING = 68,14,096 – 4900 = 6809196/-

Qualitative Benefits:

1. Ensuring SAFE running of trains .
2. Improvement in sectional capacity: Speed restriction imposed for a long period in a section will have severe repercussion in running of all the train in the section adversely affecting the line capacity utilization.

   This is all the more so if the speed restriction is already being imposed in a critical block section. Therefore, by avoiding the need of imposing speed restriction, the innovative technique will enhance the overall operational efficiency.
3. In addition, there is substantial saving in maintenance cost of track. Also, in place of 8 staff per Km, only 4 staff per Km are required to maintain track on bridge approaches for the modified pattern of foundation process.
4. Loss of punctuality of Coaching trains are avoided. This improves reliability of Railway system and increases faith of the passengers on Railways.
5. Rolling stock bearings and suspension gears are less affected due to smooth running over the bridge.

Implementation plan:

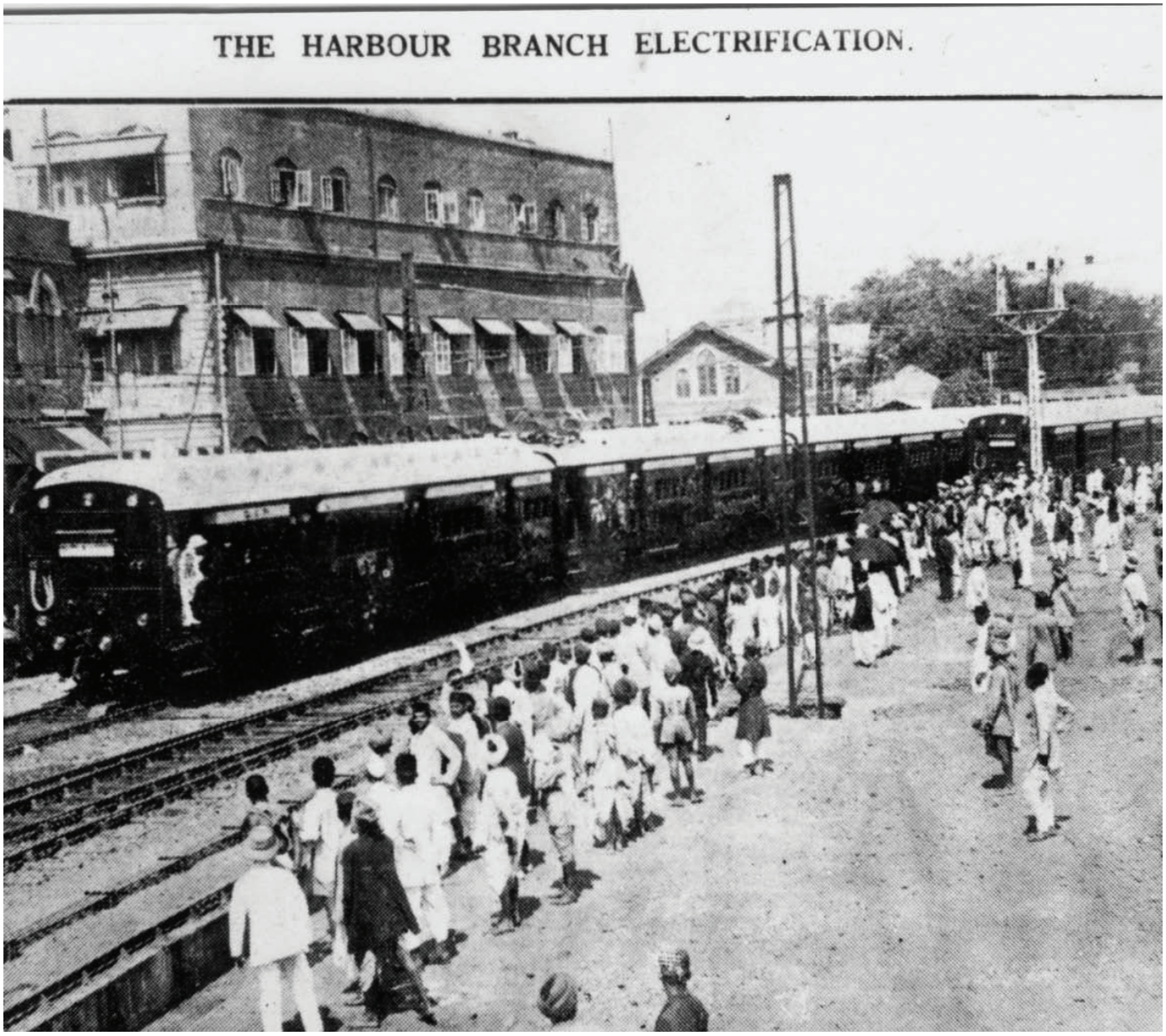
The innovative idea of filling up the voids among the boulders packed in the bridge approaches with suitable materials has already been implemented in Bridge numbers 10,11,12,13,14,15,16,17,18,19 up and 19 down in Kalmitar-Salka Road section with no instance of speed restrictions being imposed even after four months of their opening. However, in the first 10 bridges there was a slight sagging of less than 6mm noticed. In the case of Bridge number 19 down, well-graded sand instead of the standard backfill material was used and better result by way of complete absence of sagging was observed. Therefore, sand is proved to be a better packing material for the boulder. The innovative idea of fixing the Stainless steel mesh between the boulder layer and the weep hole has been tried out in Br no. 19 Dn .It is noticed in the bridge that above innovation is permitting, oozing of only water without any sign of escape of ,either sand or backfill material's fine particles. This innovation is highly beneficial to Railway's in terms of monetary benefit as well as safety of running train hence its adoption is absolutely necessary.

Conclusion :

The improved method of track formation at the approaches of bridges as projected above to prevent sagging of track at the approaches of Railway culverts or bridges can be adopted as a unified system over Indian Railways.

References:

1. Bridge Manual of Indian Railways,
2. Bridge Sub- structure Code,2003
3. RDSO Drg/M/00004/1-2 dated 21-04-05
4. Indian Railways Year Books.
5. Annual Statistical statements of Indian Railways



A Study on Ground Improvement by using Geogrid and Non-Woven Geotextile layers at Metro Car Depot at Joka, Kolkata

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ABSTRACT

This study depicts the use of ground improvement technique and monitors the settlement behavior of soil by using Geogrid and Geotextile. Geogrid with its high tensile-strength property has been used to improve soil subgrade that enhances the soil's strength for the Rigid Pavement and Ballasted Track areas of the Metro Car Depot at Joka, Kolkata. Finite Element Analysis by ABAQUS software was used to calculate the settlement. In-situ Plate Load Tests were conducted to find the actual settlement and it was observed that the values obtained are well within the predicted settlement by FEM software. The application of the Geogrid and Non-Woven Geotextile for the ground improvement was found technically effective, economic and environment friendly. The Non-woven Geotextile acts as a separator and is also required to carry tensile load at a definite strain over the design life. The Geogrid acts as a reinforcement layer between soft ground and granular fill and increases the bearing capacity in two ways, firstly by resisting the outward shear stress caused by lateral pressure and secondly by reversing the interface shear stress to act inward, thereby further increasing bearing capacity of foundation.

This paper is an effort to look into the technical issues involved & possible solutions which can be used for framing strategy to introduce 160kmph passenger train operation on IR network.

1. Introduction

Rail Vikas Nigam Limited (RVNL), a Central Public Sector Undertaking under Ministry of Railways is implementing the Metro Railway projects in Kolkata including the Joka-Esplanade Metro Corridor which is a standalone line and requires a vast Maintenance and stabling depot for the Rolling stock. At the terminating station at Joka, a Metro Depot has been set up which is spread over an area of 25.45 hectare and has a peripheral boundary of 4.3 km. The area was initially, a low lying land adjacent to the tidal canal named Charial Khal, due to which filling of the designated area for before the construction of the depot was essential.

Sub soil investigation was carried out and the soil was found to be of very poor in strength, comprising of very soft to soft, grey to bluish grey, organic, clayey silt/ silty clay with decomposed wood and other decayed organic vegetation. Thus, it was felt that ground improvement should be adopted.

2. Options for Ground improvement:

The various prevailing methods of ground improvement practices were thought of (i) conventional RCC cast in situ concrete piles (ii) Stone Columns (iii) prefabricated vertical drains (iv) grouted stone columns (v) vibro stone columns (vi) Geogrid reinforced foundation.

In this context, it is worthwhile to mention that M/s KELLER were requested to study and bring out a "Preliminary Techno-Commercial Note on optimal foundation solution for Railway Depot at Joka". They initially proposed for the Stone Columns for ground improvement.

The advantages of the stone columns as stated in the report were: (i) Suitability under earthquake loading for highly seismic area (Joka doesn't lie in highly seismic zone) (ii) Cost effective where stone is available at nearby sources (the nearest stone quarry of Panchami is located at a distance of about 240 km). The advantage as mentioned did not seem to be very cost effective for the project.

Moreover, the limitations of the recommendation where subjected to Bearing capacity > 60 kPa and Settlement < 25 mm. The limitation of the settlement was critical, considering the sub soil characteristics. Further, M/s Keller later informed later that the Grouted Stone Column method was technically not feasible as the soil with comparatively good condition (N-Value= 23-38) was located at a depth of 21 m, i.e. more than the available equipment for stone piles and hence bored cast-in -situ piles should be constructed for the areas with concrete floors including ballastless track where settlement criteria is very stringent.

The PVDs were also not found to be feasible as there was requirement of approximately 8 t/m2 load which could be provided by stacking concrete sleepers in several layers, which was practically not feasible. Further, PVD required nine (09) months which was extremely difficult proposition. Thus, taking into account the recommendation from M/s KELLER and on analysis thereof ground improvement by pile foundations was adopted for sheds and building and the Ballastless Track area, while alternative method of Geogrid reinforced foundation was proposed for the Ballasted track area and the roads considering the budgetary provisions, time bound stringent project schedule, faster construction methods, versatility for spreading load, increase in the consolidation of sub soil, enhanced bearing capacity, cost effectiveness, stress dilution, and of course environment friendly solution with lesser carbon footprint. The stiffness, shear strength and modulus of the sub soil are relatively increased, and the settlement is considerably decreased.

3. Description of the Project

The project is being implemented in two phases. The Phase-I has been commissioned and the phase-II is nearing completion.

Phase-I consists of the ground improvement using Non-Woven

Geotextiles and Geo Grids. The locations which were proposed to be improved, in this phase, include the following:

i. Inspection Shed with Lifting Bay and double Storeyed Building
ii. Store Ward
iii. Administrative Building
iv. Electric Sub Station Building
v. Pit Wheel Lathe Shed
vi. Road in the form of Rigid Pavement
vii. Ballasted Track

Phase-II consists of stabling lines in the form of ballastless tracks and the POH Shed.

As per the geotechnical investigation report, there's presence of sand layer after at least 20 m. It was recommended to use stone pile or similar ground improvement techniques to reach minimum embedment within the sand layer.

In Phase I for Rigid Road, Ballasted Track Area ground improvement by Geogrid and Geotextile has been used whereas for other locations such as Inspection Shed and Double Storeyed Building, store ward Shed, Administrative Building, Pit wheel Lathe and Electric Sub Station deep foundation in the form of bored Cast-in-situ piles have been adopted as there is stringent requirement of settlement control (less than 25 mm). For the road and ballasted track area, there is some scope available of making good if there is minor settlement.

Similarly, for the Phase-II, ground improvement by pile foundation has been used as there is stringent requirement of settlement for the POH shed as well as the Stabling lines. The stabling line area has 13 Ballastless Track line with the 3rd rail for traction.

4. Benefits of Adoption of Geogrid

The present study investigates the improvement in soil condition of the weak soil by placing Geogrid and Geotextile at different depths. Ground improvement by Geogrid reinforcement as a technique had been used for over 40 years. The high stiffness polyester Geogrid may be used as a basal reinforcement to improve the bearing capacity and reduce differential settlement. The Geogrid is required to carry tensile load over the design life.

Geotextile is a very cost-effective material. When there is a soft clay layer in the field, and a granular fill is being used over the soft clay layer, it is a common practice to provide a layer of Geogrid and Geotextile in between the layers. The Geotextile acts as a separator of the different layers and the combined effect of Geogrid and Geotextile acts as a membrane to reduce the settlement and increase the bearing capacity. When Geogrid reinforced soil is stressed, deformation will occur which is necessary to mobilize shear strength in soil and tensile resistance of the Geogrid material.

4.1 Geogrid:

Geogrid is a planar, polymeric structure consisting of a regular open network of integrally connected tensile elements, which may be linked by extrusion, bonding or interlacing. They have an open grid like configuration with large apertures between individual ribs. The key feature of all Geogrids is that the apertures are large enough to allow soil communication, or strike through, from one side of the Geogrid to the other. Geogrids have relatively high strength, high modulus and low creep sensitive polymers. High strength polyester woven Geogrid is used as basal reinforcement and acts as a reinforced embankment, over the foundation soil under working stress condition. The contribution of Geogrid as reinforcement is either viewed as stress absorbing mechanism or strain alleviating component. Woven Geogrid was used for the Joka Metro Depot as shown in figure: 1 below.



Fig. 1: Woven Geogrid

4.2. Specification of Woven Geogrid Used For JOKA-Metro Depot:

The required applicable characteristics of Geogrid specified for the Joka Metro Card Depot are given below. Both IRC: 113 and MoRTH: 3100 specifications have been adopted for the application of Geogrid at JOKA Depot Kolkata. The specification of the Woven Geogrid is given in the following Table.

Table 1: Specification of the Woven Geo-Grid

Property		Test Method	Unit	Value
Ultimate tensile strength1	MD	EN ISO: 10319:2015	kN/m	80
	CD			80
Elongation at Nominal Strength	MD		%	10
	CD			10
Tensile strength at 2% strain	MD		kN/m	13
	CD			10
Tensile strength at 5% strain	MD		kN/m	25
	CD			19
Physical Properties				
Aperture size (Tolerance ± 3 mm)			mm	21x25
Roll dimensions				
Roll length			m	100
Roll width			m	5.0
Minimum Average roll value (Minimum refers to 95 % confidence limit.)				
MD – Machine Direction CD – Cross Direction.				

4.3. Woven Geogrid test result:

The test result of the Woven Geogrid used in the project work at Joka is presented in the following Table.

Table 2: Test Result of Woven Geo-Grid

Orientation	Ultimate strength (kN/m)		Strain at Nominal strength (%)		Strength at 2% strain (kN/m)		Strength at 5% strain (kN/m)	
	Observed	Min. Required	Observed	Min. Required	Observed	Min. Required	Observed	Min. Required
MD	81.5	80	10.9	10	25.3	13	42.5	25
CMD	83.2	80	11.1	10	23.2	10	40.1	19



Fig. 2: Laying of Geogrid & Geotextile at Joka Depot under Track Formation



Fig. 3: Laying of Geogrid and Geotextile at Joka Depot under Road

4.4 Geotextile:

Geotextiles are planar and permeable members which are manufactured from synthetic fibres, yarns, filaments, tapes etc. The polymers used in manufacturing Geotextiles are Polypropylene, Polyester, High Density Polyethylene and Polyamide (nylon) or a combination thereof, but a large majority of Geotextiles are made from Polypropylene.

4.4.1 Selection of Geotextile for JOKA Depot:

At Joka Depot Non-woven Geotextile has been used in order to separate two heterogeneous layers, one being fine grained cohesive layer and other coarse grained granular layer from intermixing with each other.



Fig. 4: Non-woven Type Geo Textile



Fig. 5: Storage of Geo-Textile at site

4.4.2 Specification and Test Result of Non-Woven Geotextile:

Specification and test result of non-woven Geotextile are presented in the Table 3 below.

Table 3: Specification and Test Result of Non-Woven Geotextile

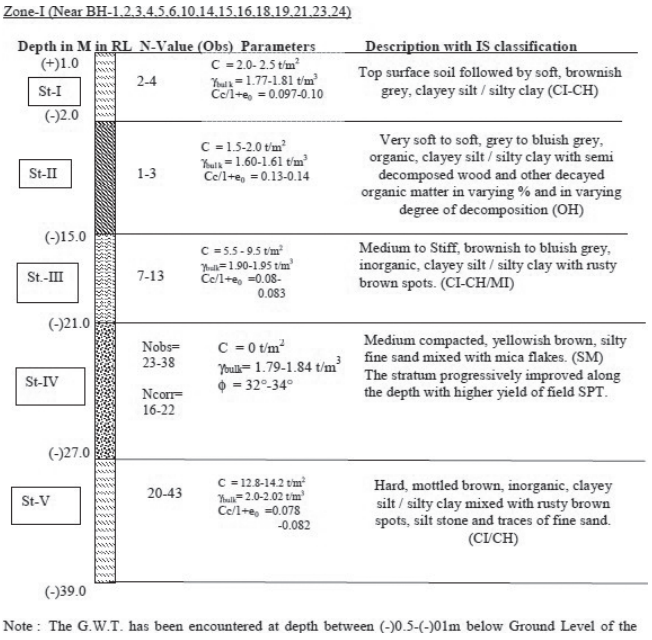
SN	Property	Value		
		Observed		Required as per RDSO Specifications
		MD	CD	
I	**Polymer and Type**			
A	Material/Polymer	Polypropylene		Polypropylene/ Polyethylene/ Polyamide, Polyester or any combination thereof
B	Type/Structure	Non-woven Needle Punched		Non-woven Needle Punched and Mechanically or Thermally Woven type or equivalent
II	**Mechanical Properties**			
	Elongation at failure	57.2%	86.1%	>50% in both directions
	Grab Strength: on top of subgrade or prepared subgrade before laying blanket or anywhere within the embankment	777.0 N	793.0 N	700N
III	**Hydraulic Properties**			
	Apparent Opening Size	75 micron	<= 85 micron	
	Water flow rate normal to plane	27.0 lit/ m2/sec	20 lit/ m2/sec	
IV	**Survivability properties**			
	Trapezoidal tear strength on top of subgrade or prepared subgrade before laying blanket or anywhere within the embankment	270.2 N	274.4 N	250 N
	Puncture strength-CBR on top of subgrade or prepared subgrade before laying blanket or anywhere within the embankment	1891 N		1800 N



Fig. 6: Laying of Geotextile at Joka Depot

5. Soil Classification and Settlement Check

The geotechnical investigation was carried out by M/s Technoma India, Kolkata and the report was provided by RVNL to M/s Mythcon. The generalized soil properties from the bore hole were presented in the report and same were adopted by M/s Mythcon for computation of settlement calculation. The generalized sub soil profile is reproduced in Figure 7 below.



Note : The G.W.T. has been encountered at depth between (-)0.5-(-)01m below Ground Level of the

Fig. 7: Generalized Sub soil profile

5.1 Settlement Calculations:

From the soil parameters mentioned in Figure 7, structure wise settlement calculations for two different conditions were made as presented in Table 4 & Table 6 respectively. Similarly, the time rate of settlement for each structure, for two different conditions of was determined as presented in Table 5 & Table 7 respectively.

Table 4: Summary of Settlement Without Preloading

Type of Structure	Live Load (kN/m)	Pressure increment (Due to sand and stone dust) (kN/m²)	Pressure increment (Due to Gravel and live load) (kN/m²)	Thick-ness (m)	Density (kN/m³)	p_0 (at middle of clay layer) (kN/m²)	Cc/ (1+e_0)	D_p (kN/m²) (Due to sand and stone dust)	Settlement (mm)	D_g (kN/m²) (Due to Sand, stone dust and live load)	Settlement (mm)
								Due to sand and stone dust		Due to Sand, stone dust and live load	
Inspection Shed (Bay 1 & 2)	20	12.384	26	3	17.56	26.34	0.097	12.36	48.625	38.38	113.61
				7	15.74	81.43	0.13	12.36	55.849	38.38	152.62
							Total Settlement		104.47		266.23
Inspection Shed (Lifting Bay)	20	31.68	26	3	17.56	26.34	0.1	31.68	99.8	57.68	146.60
				7	15.74	81.43	0.13	31.68	129.87	57.68	211.64
							Total Settlement		229.67		358.24
Store Ward	20	12.384	26	3	17.56	26.34	0.097	12.36	48.625	38.38	113.61
				7	15.74	81.43	0.13	12.36	55.849	38.38	152.62
							Total Settlement		104.47		266.23
Double Storeyed Building	20	45.702	26	3	17.56	26.34	0.097	45.7	127.16	71.7	166.10
				7	15.74	81.43	0.13	45.7	176.06	71.7	249.60
							Total Settlement		303.22		415.70
Rigid Pavement	20	18	26	3	17.56	26.34	0.097	18	65.819	44	124.14
				7	15.74	81.43	0.13	18	78.927	44	170.73
							Total Settlement		144.75		294.87
Ballasted Track	20	18	26	3	17.56	26.34	0.097	18	65.819	44	124.14
				10	15.74	105.04	0.13	18	89.299	44	197.53
							Total Settlement		155.12		321.67

Table 5: Summary of Time Rate of Settlement Without Preloading

Type of Structure	Total Settlement (mm)	Drainage Path (in cm)	Cv (cm²/s)	t (Months)	t (S)	T_v	U	Settlement (mm)
Inspection Shed (Bay -1)	266	500	Cv = .00117	1.00	2592000	0.012	12.428	33.09
				3.00	7776000	0.036	21.526	57.31
				6.00	15552000	0.073	30.442	81.05
				12.00	31104000	0.146	43.051	114.62
				24.00	62208000	0.291	60.476	161.01
				48.00	124416000	0.582	80.733	214.94
				94.00	243648000	1.140	95.139	253.29
Inspection Shed (Lifting Bay)	358.24	500	Cv = .00117	1.00	2592000	0.012	12.428	44.52
				3.00	7776000	0.036	21.526	77.11
				6.00	15552000	0.073	30.442	109.05
				12.00	31104000	0.146	43.051	154.23
				24.00	62208000	0.291	60.476	216.65
				48.00	124416000	0.582	80.733	289.22
				94.00	243648000	1.140	95.139	340.83

Store Ward	266	500	Cv = .00117	1.00	2592000	0.012	12.428	33.09
				3.00	7776000	0.036	21.526	57.31
				6.00	15552000	0.073	30.442	81.05
				12.00	31104000	0.146	43.051	114.62
				24.00	62208000	0.291	60.476	161.01
				48.00	124416000	0.582	80.733	214.94
				94.00	243648000	1.140	95.139	253.29
Double Storeyed Building	415	500	Cv = .00117	1.00	2592000	0.012	12.428	51.58
				3.00	7776000	0.036	21.526	89.33
				6.00	15552000	0.073	30.442	126.33
				12.00	31104000	0.146	43.051	178.66
				24.00	62208000	0.291	60.476	250.98
				48.00	124416000	0.582	80.733	335.04
				94.00	243648000	1.140	95.139	394.83
Rigid Pavement	295	500	Cv = .00117	1.00	2592000	0.012	12.428	36.66
				3.00	7776000	0.036	21.526	63.50
				6.00	15552000	0.073	30.442	89.80
				12.00	31104000	0.146	43.051	127.00
				24.00	62208000	0.291	60.476	178.41
				48.00	124416000	0.582	80.733	238.16
				94.00	243648000	1.140	95.139	280.66
Ballasted Track	321	500	Cv = .00117	1.00	2592000	0.012	12.428	39.89
				3.00	7776000	0.036	21.526	69.10
				6.00	15552000	0.073	30.442	97.72
				12.00	31104000	0.146	43.051	138.19
				24.00	62208000	0.291	60.476	194.13
				48.00	124416000	0.582	80.733	259.15
				94.00	243648000	1.140	95.139	305.40

Table 6: Summary of Settlement With Preloading

Type of Structure	Live Load (KN/m)	Pressure increment (Due to sand and stone dust) (kN/m^2)	Pressure increment (Due to Gravel and live load) (kN/m^2)	Thick-ness (m)	Density (kN/m^3)	p0 (at middle of clay layer) (kN/m^2)	Cs/ (1+e_0)	Dp (Due to Sand and stone dust) (kN/m^2)	Settlement (mm)	Dp (Due to Sand, stone dust, and live load) (kN/m^2)	Settlement (mm)
								Due to sand and stone dust		Due to Sand, stone dust, and live load	
Inspection Shed (Bay 1 & 2)	20	12.384	26	3	17.56	26.34	0.02	12.36	12.16	38.38	28.40
				7	15.74	81.43	0.03	12.36	13.96	38.38	38.15
							Total Settlement		26.12		66.56
Inspection Shed (Lifting Bay)	20	31.68	26	3	17.56	26.34	0.02	31.68	24.69	57.68	36.27
				7	15.74	81.43	0.03	31.68	32.97	57.68	53.72
							Total Settlement		57.66		90.00
Store Ward	20	12.384	26	3	17.56	26.34	0.02	12.36	12.03	38.38	28.11
				7	15.74	81.43	0.03	12.36	14.18	38.38	38.74
							Total Settlement		26.21		66.85

Double Storeyed Building	20	45.702	26	3	17.56	26.34	0.02	45.70	31.46	71.70	41.10
				7	15.74	81.43	0.03	45.70	44.69	71.70	63.36
							Total Settlement		76.15		####
Rigid Pavement	20	18	26	3	17.56	26.34	0.02	18.00	16.29	44.00	30.71
				7	15.74	81.43	0.03	18.00	20.04	44.00	43.34
							Total Settlement		36.32		74.05
Ballasted Track	20	18	26	3	17.56	26.34	0.02	18.00	16.29	44.00	30.71
				10	15.74	105.04	0.03	18.00	22.67	44.00	50.14
							Total Settlement		38.95		80.86

Table 7: Summary of Time Rate of Settlement with Preloading

Type of Structure	Total Settlement (mm)	Drainage Path (in cm)	Cv (cm^2/s)	t (Months)	t (S)	Tv	U	Settlement (mm)
Inspection Shed (Bay -1)	66	500	Cv = .00117	1.00	2592000	0.012	12.428	8.20
				3.00	7776000	0.036	21.526	14.21
				6.00	15552000	0.073	30.442	20.09
				12.00	31104000	0.146	43.051	28.41
				24.00	62208000	0.291	60.476	39.91
				48.00	124416000	0.582	80.733	53.28
				94.00	243648000	1.140	95.139	62.79
Inspection Shed (Lifting Bay)	90	500	Cv = .00117	1.00	2592000	0.012	12.428	11.19
				3.00	7776000	0.036	21.526	19.37
				6.00	15552000	0.073	30.442	27.40
				12.00	31104000	0.146	43.051	38.75
				24.00	62208000	0.291	60.476	54.43
				48.00	124416000	0.582	80.733	72.66
				94.00	243648000	1.140	95.139	85.62
Store Ward	67	500	Cv = .00117	1.00	2592000	0.012	12.428	8.33
				3.00	7776000	0.036	21.526	14.42
				6.00	15552000	0.073	30.442	20.40
				12.00	31104000	0.146	43.051	28.84
				24.00	62208000	0.291	60.476	40.52
				48.00	124416000	0.582	80.733	54.09
				94.00	243648000	1.140	95.139	63.74
Double Storeyed Building	104	500	Cv = .00117	1.00	2592000	0.012	12.428	12.92
				3.00	7776000	0.036	21.526	22.39
				6.00	15552000	0.073	30.442	31.66
				12.00	31104000	0.146	43.051	44.77
				24.00	62208000	0.291	60.476	62.90
				48.00	124416000	0.582	80.733	83.96
				94.00	243648000	1.140	95.139	98.94
Rigid Pavement	74	500	Cv = .00117	1.00	2592000	0.012	12.428	9.20
				3.00	7776000	0.036	21.526	15.93
				6.00	15552000	0.073	30.442	22.53
				12.00	31104000	0.146	43.051	31.86
				24.00	62208000	0.291	60.476	44.75
				48.00	124416000	0.582	80.733	59.74
				94.00	243648000	1.140	95.139	70.40

Ballasted Track	81	500	Cv = .00117	1.00	2592000	0.012	12.428	10.07
				3.00	7776000	0.036	21.526	17.44
				6.00	15552000	0.073	30.442	24.66
				12.00	31104000	0.146	43.051	34.87
				24.00	62208000	0.291	60.476	48.99
				48.00	124416000	0.582	80.733	65.39
				94.00	243648000	1.140	95.139	77.06

6. Structures Proposed with Geogrid and Geotextile

As mentioned under Cl. 2.0, Geogrid with geotextile was proposed for the Rigid Pavement and Ballasted Track areas. Typical cross sections for the two are presented below in figures 8 and 9 respectively.

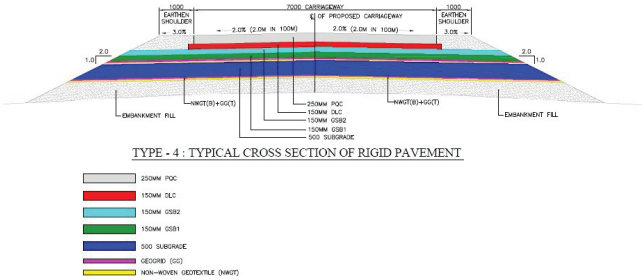


Fig. 8: Typical cross section of Rigid Pavement

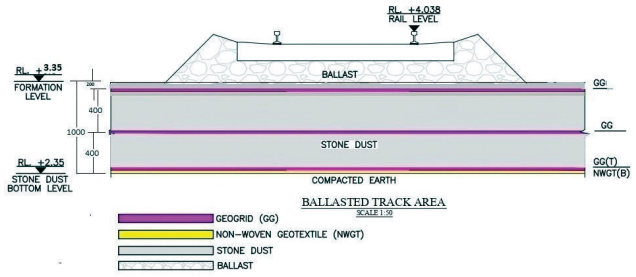


Fig. 9: Typical cross section of Ballasted Track Area

7. Finite Element Analysis (Fem) by Using Abaqus Software

A finite element model using commercially available FEM software 'ABAQUS' has been made to analyze the performance of Geogrid and Non-woven Geotextile on the embankment fill. The computed value by using the ABAQUS software shows the immediate settlement under the condition with the use of Geogrid and geotextile which comes out to be less. Hence the use of the same for ground improvement is justified.

The values of the settlement as calculated from FEM is presented in the Table 8 below.

Table 8: Summary of Settlement Calculated by FEM

Section Details	Total Settlement (Without preloading) (in mm)		Total Settlement (After preloading) (in mm)		FEM (in mm)
	Sand + Stone Dust	Sand + Stone Dust + Live Load	Sand+ Stone Dust	Sand + Stone Dust +Live Load	
Rigid Pavement	144.75	294.87	36.32	74.05	16
Ballasted Track Area	155.12	321.67	38.95	80.86	14

7.1 Rigid Pavement:

In the FEM, the mesh and boundary conditions for the Rigid pavement are presented as in Figure 10. Considering a UDL of 30 kN/m, the pavement component layers as per the FEM are depicted in Figure 11. In Figure 12, the FEM output data is provided, showing the maximum displacement of 16 mm.

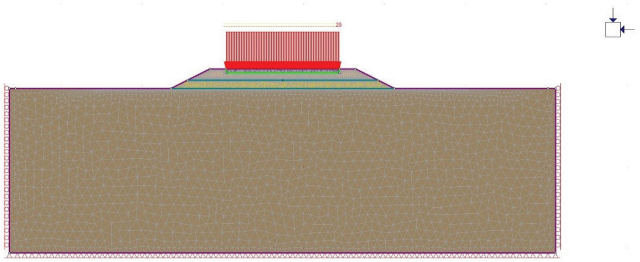


Fig. 10: Mesh and boundary condition for Rigid pavement

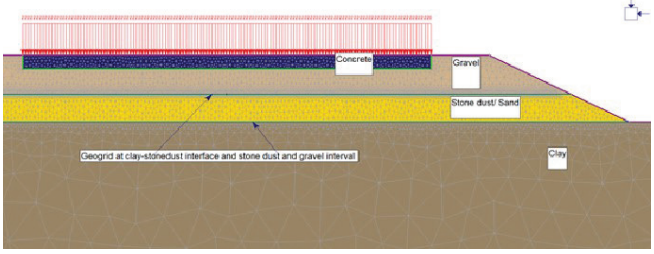


Fig. 11: UDL of 30 kN/m applied for Rigid pavement

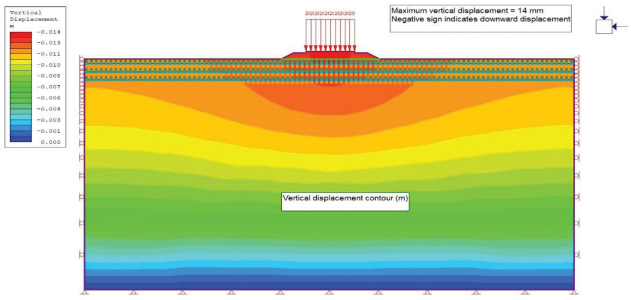


Fig. 12: Max displacement of 16mm with Geogrid & Geotextile for Rigid Pavement

7.2 Ballasted Track:

In the FEM, the mesh and boundary conditions for the Ballasted Track are presented in figures 13 and 14 respectively. Considering a UDL of 20 kN/m, the pavement component layers as per the FEM are depicted in figures 15. In figure 16, the FEM output data is provided, showing the maximum displacement of 14 mm.

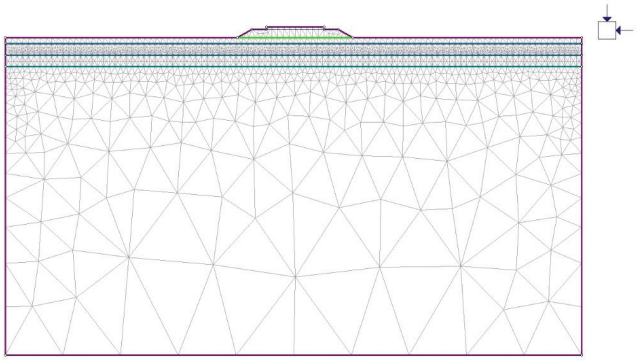


Fig. 13: Mesh for Ballasted Track

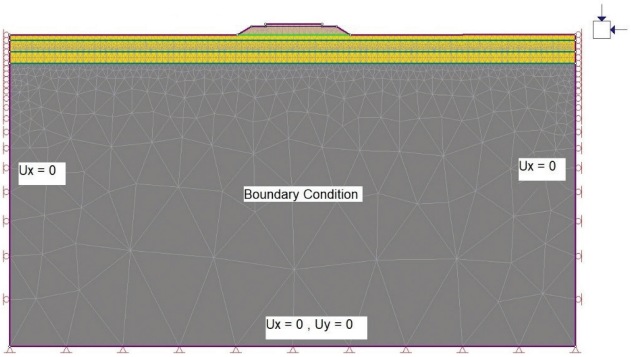


Fig. 14: Boundary condition for Ballasted Track

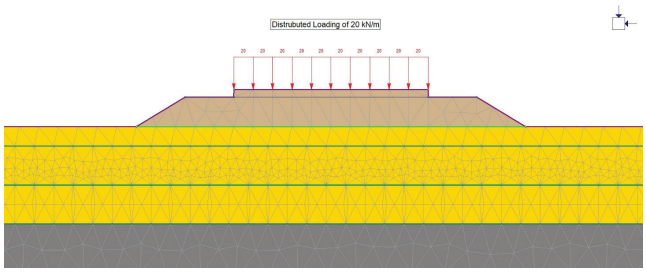


Fig. 15: UDL of 20 kN/m applied for Ballasted Track

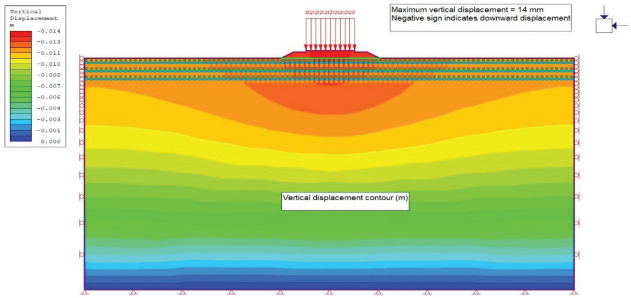


Fig. 16: Max displacement of 14 mm with Geogrid & Geotextile for Ballasted Track

8. Plate Load Test (Strain Modulus EV2)

Elastic modulus (Ev2) at second loading was determined by conducting plate load test by static method. Load was applied and released in increments using a circular loading plate (300 mm dia) aided by a loading device and the settlement of the loading plate being measured.

Strain modulus is the parameter expressing the deformation characteristics of the soil, calculated from the secants of the load-settlement curves obtained from the first or repeat loading cycle between points 0.3 max and 0.7 max•, conducted as per "DIN 18134:2012" where symbols have their usual meaning as given in the standard code.

Ev2 test was conducted in the ballasted track area for the assessment of strength improvement of underlying layers by provision of layers of Geogrid and Geotextile. EV2 Test was conducted on soil layers prepared as per the proposed cross-section (Fig. 9) as well as on the bed without the use of Geogrid and Geotextile, keeping all other conditions same for the purpose of comparison. From the following table, it is observed that with provision of layers of Geotextile and Geogrid, the strength characteristics improved.

The comparative values of deformation modulus with & without the use of Geogrid & Geotextile are presented in Table 9 below.

Table 9: Comparision of Deformation Modulus Values With & Without Use of Geogrid & Geotextile

	Case-1		Case-2		Case-3	
Level at which EV2 Test Conducted (Compacted Earth Leve: 0.0 mm)	Geogrid (GG) and Geotextile (GT)	EV2 (MN/ m2)	Geogrid (GG) and Geotextile (GT)	EV2 (MN/ m^2)	Geogrid (GG) and Geotextile (GT)	EV2 (MN/ m^2)
+400 mm	No	71.9	Geogrid and Geotextile at +0.0 m (Cumulative GG-1 and GT-1)	80.4	Geogrid and Geotextile at +0.0 m (Cumulative GG-1 and GT-1)	84.2
+600 mm	No	88.0	Add Geogrid at +400 mm (Cumulative GG-2 and GT-1)	90.4	Add Geogrid and Geotextile at +400 m (Cumulative GG-2 and GT-2)	94.7

+800 mm	No	89.4	Same as above (Cumulative GG-2 and GT-1)	105.4	Add Geogrid and Geotextile at +600 mm (Cumulative GG-3 and GT-3)	106.0
+1000 mm	No	100.1	Add Geogrid at +800 mm (Cumulative GG-3 and GT-1)	116.4	Add Geogrid and Geotextile at +800 mm (Cumulative GG-4 and GT-4)	133.1

8.1 Conclusion for Ev2 Test:

Ev2 Plate load test had been conducted to find out the strain modulus (Ev2) of the soil strata. Ev2 Test was conducted at the Test track location of the Metro Car Depot, with 3 layers of Geogrid and one layer of Geotextile as given in the cross-section and the values obtained at 400mm, 600mm, 800mm and 1000mm above the compacted earth are 80.4MPa, 90.4MPa, 105.4MPa and 116.4MPa respectively. With 4 layers of Geogrid and Geotextile, the values obtained at 400mm, 600mm, 800mm and 1000mm above the compacted earth are 84.2 MPa, 94.7 MPa, 106.0 MPa and 133.1 MPa respectively. When the same Test was conducted at a nearby location without the use of Geogrid and Geotextile, but keeping other conditions same as the previous case, the EV2 values found at the respective levels were 71.9 MPa, 88.0 MPa, 89.4 MPa and 100.1 MPa respectively.

9. Settlement Check by In-Situ Plate Load Test on Geogrid and Geotextile Reinforced Embankment After Preloading

Three Plate Load Tests had been conducted by using 450 mm x 450 mm square plate on the formation Bed areas named A1, A2 and A3 Beds in the Metro Car Depot on Geogrid and Geotextile reinforced embankment. The details regarding the duration of tests, loading and settlement observed are provided in the Table 10 below. The actual settlements observed from the plate load tests were compared with predicted settlement from the FEM and were found to be less. The vertical displacement calculated by FEM was a conservative estimate of the immediate settlement.

Table 10: Summary of In-situ Plate Load Test

Test No	Start date	End date	Period of test in weeks (approximate)	Total loading (on 450X450 mm Test plate) (MT)	Settlement observed (mm)
1	06.12.2021 (A2 Bed)	06.02.2022	8.5 weeks	1.272	4.837
2	02.03.2022 (A3 Bed)	03.05.2022	8.5 weeks	1.272	0.972
3	19.05.2022 (A1 Bed)	20.07.2022	8.5 weeks	1.272	1.725

10. Cost Effectiveness of Geogrid and Geotextile:

The soil quality at Joka Depot site being very poor, the feasible options without considering the time aspect, were Pile Foundation and the Geogrid and Geotextile. The Ballasted track area and the road Pavement area being very vast, being 89,356 SQM, it was decided to go for Geogrid and Geotextile layers. The cost of the land development by this method was about Rs1556/m2. If pile foundations were done in this area, the cost of pile foundation work alone would have been about Rs 10271/m2 without the cost of slab/beams, considering the piles at 3.5m c/c distance. Further, this would have taken tremendous time and the project cost would have been affected considerably. From the above data it can be clearly seen that there is significant saving in cost when using Geogrid and Geotextile, which proves the economic effectiveness of the material.

11. Conclusion

- The adopted mechanism for ground improvement with Geotextile and Geogrid reinforcement for the JOKA Metro Car Depot has been found to be technically and economically feasible. The Field application of Geogrid and Geotextile is an easy and fast method of ground improvement as well as very cost effective compared to bored cast-in-situ pile foundation and stone pile foundation.
- The FEM analysis by ABAQUS software had been carried out for the rigid road pavement and ballasted track area to evaluate the immediate settlement. The actual settlement of the soil was found out by conducting in-situ plate load test. The results of the test indicated that the settlement of the soil is considerably reduced. Further, the test load was kept for a period of 2 Months and settlement values were observed which indicated the settlement to be within the limits. The results of the test indicate that the application of Geogrid and Geotextile have improved the Soil characteristics.

12. References:

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MAHATMA GANDHIJI TRAVELLED EXTENSIVELY BY TRAIN DURING THE INDEPENDENCE STRUGGLE.

Skew Slab Bridges for Railway Loadings-Review

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ABSTRACT

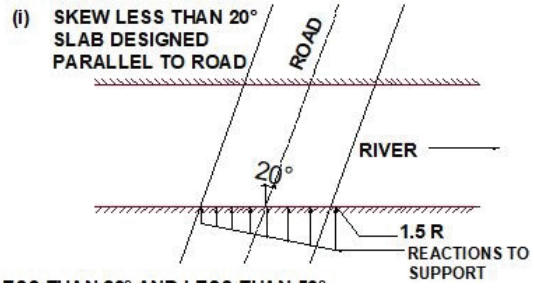
Skew crossings are necessary when a track crosses stream or the road at an angle different from 90 º. Present day traffic requirements demand straight alignment of the track in view of the fast traffic and this in turn necessitates the use of skew crossings. The provisions vide clause 15.9.10 in the IRS Concrete Bridge code 2014 on skew slabs are detailed. About Railway loadings and Coefficient of dynamic augment (CDA) are discussed. Additional pressure due to reaction at Support at obtuse corners of skew slab are narrated. The details of various analysis equations and Design of skew slab are furnished. The ready-made charts for arriving deflection along skew span for design and test loads are depicted with concerned equations. Use of WOODARMER equations for arriving design moments incorporating twisting moment due to skew effect for IRC loadings are stated. Flow charts for design of skew bridges for IRS and IRC loadings are shown for guidance. Various type of reinforcement detailing for IRS/IRC loading standard are exhibited for adopting appropriately different range of skew angles. The structural arrangement/measures to combat with the effect of creep , layout of bearing and expansion joints are reviewed. Static analysis are done for distinctive skew angles and for same aspect ratios, loading situations together with dead load, live load of Indian Railway Standard (IRS). Preliminary sample design details for different span/skew angles with different grade of concrete are exhibited for IRS and IRC loadings.

1. Introduction

Skew bridges are common in Railways, highways and railway lines when non perpendicular crossings are encountered.

once in a while supports may not be orthogonal to the traffic route necessitated by many reasons. Such bridge decks are defined as skew bridge decks. The structural effect of skewness is an additional torsion on the bridge deck which may have a considerable effect, making its analysis and design more complex In this paper, the behaviour of skew bridges due to railway traffic is analysed and studied. An analytical model following a simplified 2D model is also considered which includes only vertical beam bending. A parametric study for a large number of bridges is performed with the simplified Depending upon the skew angle the following design principles have been explained based on available theoretical investigations.

The design of skew slab bridges depends on the skew span and skew angle. When the skew angle is upto 20º, the skew slab is designed for skew span and skew loading parallel to the direction of traffic and the main reinforcement laid parallel to the c/c line of track/road way. When the skew angle is lies between 20º to 50º the skew slab is designed for square span and square loading parallel to the direction of traffic and the main reinforcement arrived is multiplied by [sec (θ)]^2 This reinforcement is laid parallel to the c/c line of track / road way. The reaction at obtuse corner is increased by 50% for skew angle upto 20º and the same shall be increased by (50% to 90%) for the skew angle varying between (20ºto 50º). When the skew angle exceeds 50º, the skew slab is designed with T-girders or I-girders. (K.L.Rao).



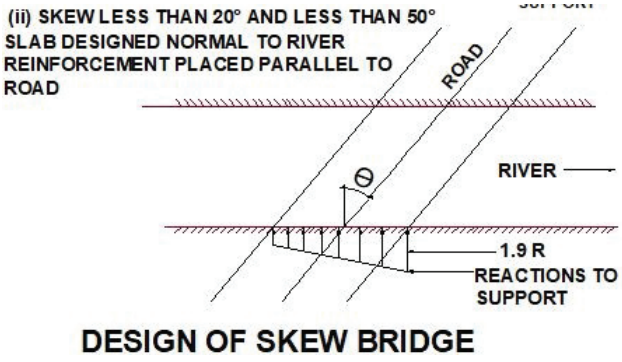


Fig .1 Skew slab models with Obtuse Diagonal reactions.(K.L. Rao Models)

1.1.The provisions vide clause 15.9.10 in the IRS Concrete Br code 2014 on skew slabs

1.1.a).The reinforcement or prestressing tendons shall be provided in the direction of traffic to the principal moment directions for combating with the effect of torsion in addition to Bending moment and shear duly following an orthogonal arrangement .

1.1. b). Only for combinations of large skew angle(θ) and low ratio of skew breadth to skew span $\left[\frac{\text{Barrel length}}{L_{skew}}\right]$, it is suitable to provide reinforcement in directions perpendicular and parallel to the free edges.

1.1.c) For Alternate cases providing reinforcement parallel and perpendicular to the supports with bends anchorage bars of reinforcement laid adjacent and parallel to the free edges are highly feasible and workable.

1.1.d) In Solid composite slabs, The longitudinal steel / prestressing tendons in the precast units, cast-in-situ are parallel to the free edges with the transverse reinforcement laid at right-angles to the free edge, or at a different angle or parallel to the supports.

1.2 Railway loadings

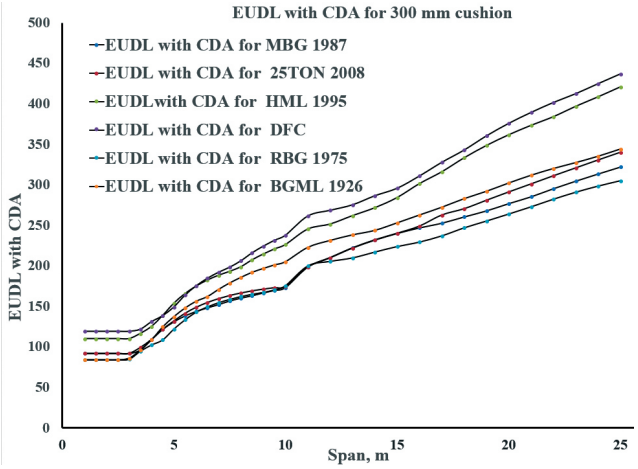


Fig. 2 EUDL with CDA (BM,tons) vs. Spans (m) for various standard of IRS loading for 300 mm cushion

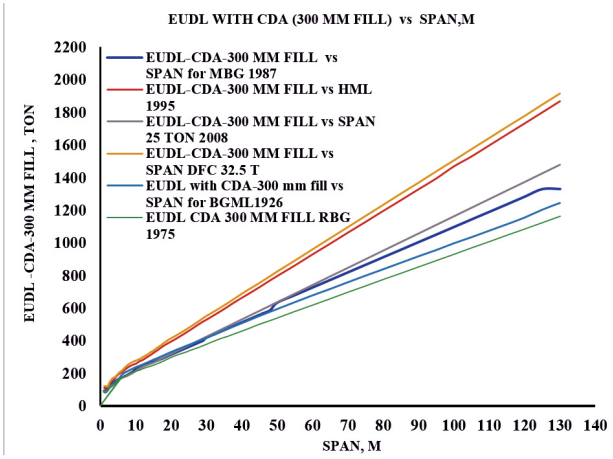


Fig. 3 EUDL with CDA (SF,tons) vs. Spans (m) for various standard of IRS loading for 300 mm cushion

The IRS loading consists of various standards. The bridges are designed using the EUDL for shear and bending moment. The values of EUDL with CDA under BM and Shear consideration for various standards are shown in Fig. 2 and Fig. 3 for 300 mm cushion respectively.

1.3 Reaction at Support:

As the planes of maximum stresses are not parallel to the centre line of the track load and as a consequence of this, the slab tends to be warped, resulting in larger reactions at the obtuse angled ends of the slab. It has been observed that due to the effect of skew, the reactions at supports are not equal but the same is more at obtuse angle comers and less at acute angle corners depending on the angle of skew. For skews up-to 20º, the increase, in the reaction on the obtuse angle corners is zero to 50 per cent and for skews from 20º to 50º, the increase is from 50 percent to 90 percent of the average reaction. The reaction on the obtuse angle corner becomes twice the average reaction thus making the acute angle corner a zero pressure point as in Fig. 4 when the skew angle reaches about 60º.

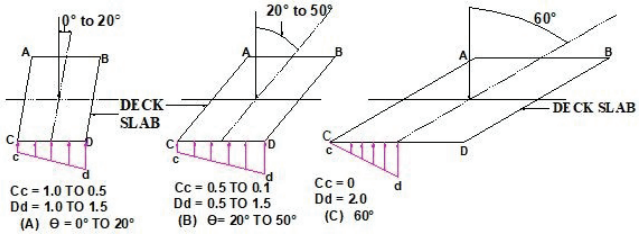


Fig. 4 Variation of reaction on support for slab having varies angle of skew

1.4 Analysis Equations and Design

The structures are generally analyzed by static methods. Selection of an appropriate method depends upon the several factors such factors includes importance of analysis, importance of structure, type of the structures. Structures are designed in such way that it should carry self-weight, live loads, super imposed loads and wind loads. These loads are considered as maximum load taken by the structure and they are static in nature

1.4.a).The CDA is the Coefficient of Dynamic Augment. For the IRS loadings i.e. MBG 1987, HML 1995, DFC32.5 and 25t 2008, the CDA for ballasted deck is given by

$$\text{CDA} = \left[\left(2-\frac{d}{0.9}\right)\times 0.5\times\left\{0.15+\frac{8}{(6+L)}\right\}\right]$$

1.4.b).For skew slab here the L is effective skew span in m. For the IRS loadings i.e. BGML 1926, the CDA for ballasted deck is given by

$$\text{CDA} = \left[\left(2-\frac{d}{0.9}\right)\times 0.5\times\left\{\frac{20}{(14+L)}\right\}\right]$$

1.4.c).The mid-span Bending Moment for effective skew span and loading (W-total design load on span) along skew span is given by

$$\textbf{Max BM}, M_{XY} = \frac{W\times L}{8}, M_x = M_{xy}\times\cos(90-\theta), M_y = M_{xy}\times\cos(\theta)$$

1.4.d).The Max shear force for overall skew span and loading (W-total design load on span) along skew span is given by

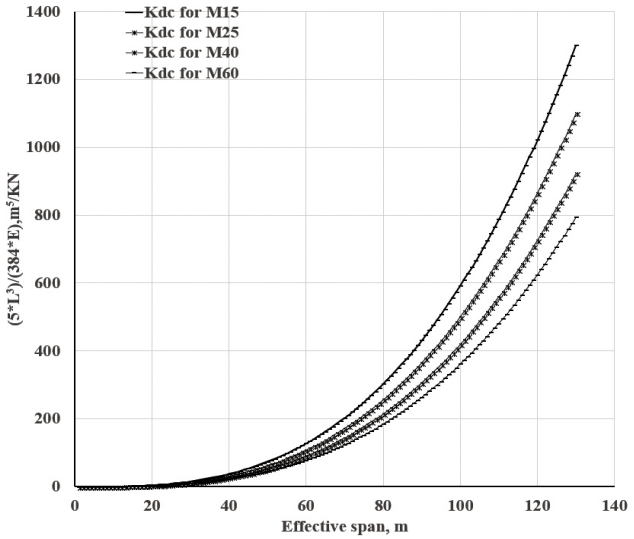
$$\textbf{Max S.F} = \frac{W}{2}$$

$$\textbf{Design Shear force} - (1.3 \text{ to } 1.55)\times\frac{W}{2}$$

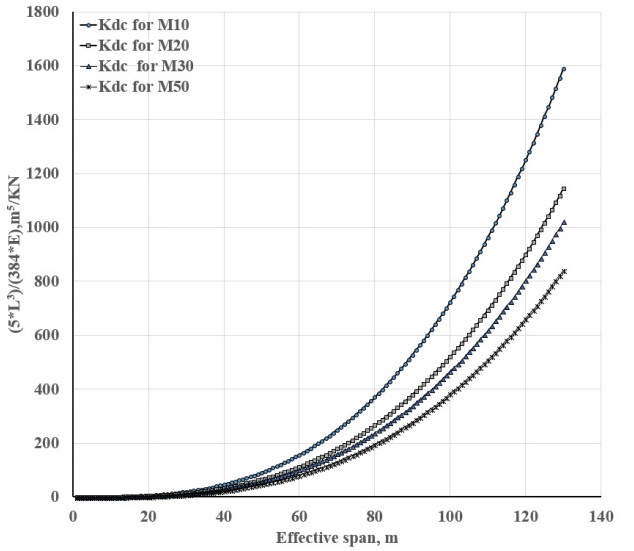
1.4.e).The maximum mid-span deflection for effective skew span and loading (i.e.total design load W=w×l) along skew span is given by

$$\textit{Max midspan deflection} = \frac{5\times W\times L^3}{384\times E\times I} = \frac{K_{dc}\times W}{I}$$

1.5. Theoretical deflection of RC members for Design and Test loads



5.a. Deflection coefficient (K_{dc}) for M15,M25, M40 and M60



5.b. Deflection coefficient (K_{dc}) for M10, M20, M30 and M50

Fig. 5 Deflection coefficient (K_{dc}) for varying grades of concrete

Using the deflection coefficient (K_{dc}), theoretical deflection for design and test loads are arrived using the following equations. The Fig. 5 shows the Deflection coefficient (K_{dc}) for varying grades of concrete under design and test loads.

1.5.a). For design load(W), deflection, $\left(\square = \frac{(K_{dc} \times DESIGN\ LOAD)}{(I)}\right)$ Where Design load is sum of EUDL with CDA,DL+SIDL in KN and I is the moment of inertia of RC member designed at mid span in m4.

1.5. b). For Test load(WT), deflection, $\left(\square_{dc} = \frac{(K_{dc} \times TEST\ LOAD)}{(I)}\right)$, Where Test load is sum of Part Test load, DL+SIDL in KN and I is the moment of inertia of RC member tested at mid span in m4. T

Midspan deflection for square span$\leq \frac{L}{500}$

1.6.Application of WOODARMER equatiins.

These equations are used to arrive for accurate design moments incorporating possible twisting moments resulting from the effect of skew based on plate element theory for IRC loadings.

$$\mathbf{M_a} = \frac{(\mathbf{Mx}+\mathbf{My})}{\mathbf{2}} + \frac{(\mathbf{Mx}-\mathbf{My})}{\mathbf{2}}\ \mathbf{cos\ (2\alpha)} + \mathbf{M_{XY}\ sin\ (2\alpha)}$$

$$M_b = \frac{(Mx+My)}{2} - \frac{(Mx-My)}{2}\cos(2\alpha) - M_{XY}\sin(2\alpha)$$

$$M_{ab} = -\frac{(Mx-My)}{2}\sin(2\alpha) + M_{XY}\cos(2\alpha)$$

$$\boldsymbol{When\ M_{ud1} > 0\ \&M_{ud2} > 0,}$$

$$M_{ud1} = M_a - \frac{M_b cos\,\phi}{(1+cos\phi)} + \frac{M_{ab}\,(1-cos\,2\phi)}{sin\phi}$$

$$M_{ud2} = \frac{M_a}{(1+cos\phi)} + \frac{M_{ab}}{sin\phi}$$

$$\mathbf{When\ M_{ud1} < 0\ \&M_{ud2} > 0}$$

$$M_{ud2} = \frac{(M_a * M_b - M_{ab}^2)}{(M_a(\sin\phi)^2 + M_b(\cos\phi)^2 - M_{ab}\ (\sin 2\phi))}$$

$$M_{ud1} = 0$$

$$\boldsymbol{When\ M_{ud1} > 0\ \&M_{ud2} < 0, M_{ud2} = 0}$$

$$\boldsymbol{M_{ud1}} = \frac{(M_a * M_b - M_{ab}^2)}{(M_a(\sin\phi)^2 + M_b(\cos\phi)^2 - M_{ab}\ (\sin 2\phi))}$$

$$\boldsymbol{When\ M_{ud1} < 0, M_{ud2} < 0, M_{ud1} = 0, M_{ud2} = 0}$$

1.6.b) Top Rebar

$$M'_{ud1} = M_a + \frac{M_b cos\,\phi}{(1-cos\phi)} - \frac{M_{ab\ (1+}cos\,2\phi)}{sin\phi}$$

$$M'_{ud2} = \frac{M_b}{(1-cos\phi)} - \frac{M_{ab}}{sin\phi}$$

$$\boldsymbol{When\ M'_{ud1} < 0\ \&M'_{ud2} < 0}$$

$$M'_{ud1} = M_a + \frac{M_b cos\,\phi}{(1-cos\phi)} - \frac{M_{ab\ (1+}cos\,2\phi)}{sin\phi}$$

$$M'_{ud2} = \frac{M_b}{(1-cos\phi)} - \frac{M_{ab}}{sin\phi}$$

$$\boldsymbol{When\ M'_{ud1} > 0\ \&M'_{ud2} < 0, M'_{ud1} = 0}$$

$$M'_{ud2} = \frac{M_b}{\boldsymbol{M_{ab}}^2/M_a}$$

$$\boldsymbol{When\ M'_{ud1} < 0\ \&M'_{ud2} > 0}$$

$$M'_{ud1} = \frac{M_a}{\boldsymbol{M_{ab}}^2/M_b}, M'_{ud2} = 0$$

$$\boldsymbol{When\ M'_{ud1} > 0\ \&M'_{ud2} > 0}$$

$$M'_{ud1} = 0, M'_{ud2} = 0$$

2.Design of Skew Bridges

The behaviour of skew bridges differs widely from that of normal bridges and therefore, the design of skew bridges needs special attention. In normal bridges, the deck slab is perpendicular to the supports and as such the load placed on the deck slab is transferred to the supports which are placed normal to the slab.

Load transference from a skew slab bridge, on the other-hand, is a complicated problem because there remains always a doubt as to the direction in which the slab will span and the manner in which the load will be transferred to the support.

An approximate method of design has been evolved for smaller skew angles less than 15 degrees. In this method the bending moments are calculated as for a right bridge of span length measured centre to centre of supports and parallel to the centre line of the roadway. The main reinforcements are provided in a direction parallel to the centre line of the roadway. Distribution reinforcement constituting 0.2 per cent of the cross-section of the slab is provided

in a direction parallel to the supports as shown in Fig. 14.

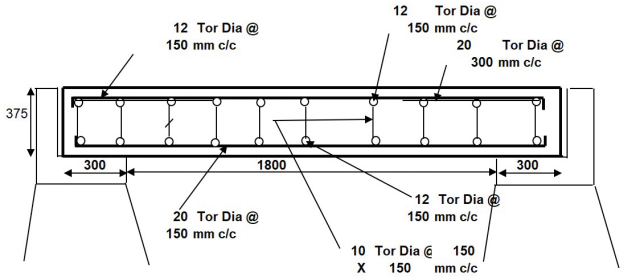


Fig. 6 Longitudinal Section of RC Slab Bridge

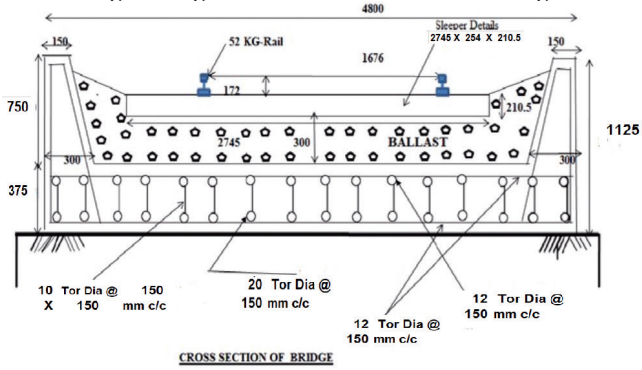


Fig. 7 Cross Section of RC Slab Bridge

Table 1. IRS and IS code provisions of various aspects (for beams and slabs)

Clauses of codes	IRS concrete Bridge code 2014	IS 456-2000	IRC 112-2011
Minimum reinforcement for tension	$\frac{0.2 \times (b \times d)}{100}$ *(Cl.15.9.4.1)*	$\frac{0.85 \times b \times d}{F_Y}$ *(Cl. 26.5.1.1.a)*	*0.0013 X bd* (Cl.16.5.1.1 .1) -------
Minimum % of steel for compression ----- -----	$\frac{\left(\frac{0.3}{2}\right)\times(b\times d)}{100}$. *(Cl.16.9.4.2.4 .i)*	Maximum of $\left[\text{(i).}\ 0.0012 \times bd,\ \text{(ii).}\ \frac{C_{uf}}{\min \text{ of } F_{ys}}\right]$ *(Cl. 25.1.11&F_{ys} as in iii & iv of Table.22)*	*0.01x b x dc (12.3.3.4 &16.5.4.4)* ------ ------ ------
Side face reinforcement	0.05% bd on each face *(15.9.4.2)*	0.1% of bd *(Cl. 26.5.1.3)*	*>150 mm2 (Cl.16.9.4)*
Spacing of main bar shall not exceed -----	300 mm (cl. 15.9.8.2.1) ----- -----	300 mm (Table 15. Clear Distance Between Bars.)	300 mm (Cl.12.3.6,Table 12.3) -----
Spacing of stirrups shall not exceed	450 mm or 0.75 d (cl.15.4.3.2.4)	300 mm or 0.75 d (Cl. 26.5.1.5) -----	600 mm or 0.75d (Cl.16.5.2.7 &16.5.2.9)
Maximum area of tension reinforcement	0.04 X B X D (Cl.15.9.5.1) ---- ----	0.04 X b X D (Cl. 26.5.1.1.b) ----- -----	(0.025) X Ac (Cl.16.5.1.1 .2) -----
Maximum area of compression reinforcement	0.04 X B X D (Cl.15.9.5.1)	0.04 X b X D (Cl. 26.5.1.2)	(0.04/2) X Ac (Cl.16.5.1.1 .2)

Table 2 Design Steps of Skew slabs for IRS/IRC loadings

IRC-Loading (Class AA/70R/AA)

STEP:1 (INPUT DATA)
1) Skew span(L_{sk}), 2)No footpath, 3)Skew angle(θ), 4) IRS loading, 5)Grade of concrete, 6)Grade of steel, 7)Dia of main bar(d_m), 8) Dia of Dist. Bar (d_d), 9) Dia of shear bar(d_s)

STEP:2 (DIMENSIONING)
1) $(L_{sq}) = (L_{sk})$ X COS(θ), 2) $(L_{efs}) = (L_{sq}) + (d_{eff})$
3) (d_{eff})=(d)- (d_{ec}) 4) $(d_{ec}) = (d_c) + 0.5x\ (d_m)$

STEP:3 (LOADS ANALYSIS)
1) DL BM= W_d X L_{efs} $^2/_8$
2) LL BM = W(L_{efs})/8 for IRC loading
3) Shear I at obtuse corner due to DL = (1.3 to 1.55) x $R_{DL-obtuse}$
4) Shear II = LL reaction (R_{LL}) due to IRC loading
5) Torsional moments by WOOD ARMER Eqns.
6) M_d for Dist steel =0.3M_{LL}+0.2M_D(Clause.305.18 of IRC-21-2000)

STEP:4 (Designing Reinforcement)
1)Flexural $A_{st-skew} = \frac{M}{(fxa)'}$ 2) Flexural $A_{st-square} = \frac{A_{st-skew}}{\sec^2(\theta)}$, and detailing as per clause 16.5.1.1 and 16.6.1.1 of IRC-112-2011. 3) Dist. $A_{std} = \frac{M_d}{(fxa)}$& as per clause 16.6.1.1.3 of IRC-112-2011 (20% of main Ast or 0.2 % of bd). 4) Shear &Torsional bars shall be as per clause 16.5.2&16.6.2 IRC-112-2011

STEP:5 (Corner reinforcement at obtuse corner)
1) Provide main bars at double spacing over $\left(\frac{L_{skew}}{4} \times \frac{L_{skew}}{4}\right)$ area at corners in orthogonal directions to both sides at top and bottom as shown in MOST-SD_151-176 and BD-10-13,1974.Drawings for skew slab as per clause 16.6.1.5.(clause 9.4.6 of BIS -SP-34) and clause16.6.1.5,16.2.3.8 of IRC 112-2011

IRS-Loading-(BGML1926,RBG1975, MBG1987 , HML 1995, DFC32.5,25t 2008)

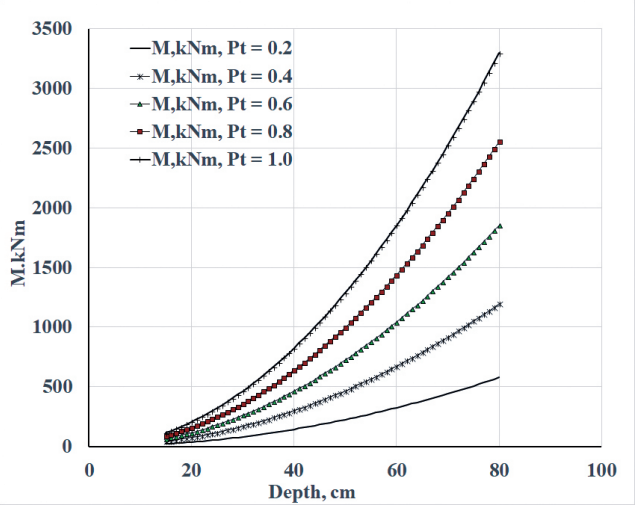
STEP:1 (INPUT DATA)
1)Skew span(L_{sk}), 2) No footpath, 3)Skew angle(θ), 4)IRS loading , 5)Grade of concrete, 6)Grade of steel ,7)Dia of main bar(d_m) 8) Dia of Dist.Bar (d_d) 9) Dia of shear bar(d_s)

STEP:2 (DIMENSIONING)
1) $(L_{sq}) = (L_{sk})$ X COS(θ), 2) $(L_{efs}) = (L_{sq}) + (d_{eff})$,3) (d_{eff})=(d)- (d_{ec})
4) $(d_{ec}) = (d_c) + 0.5x\ (d_m)$

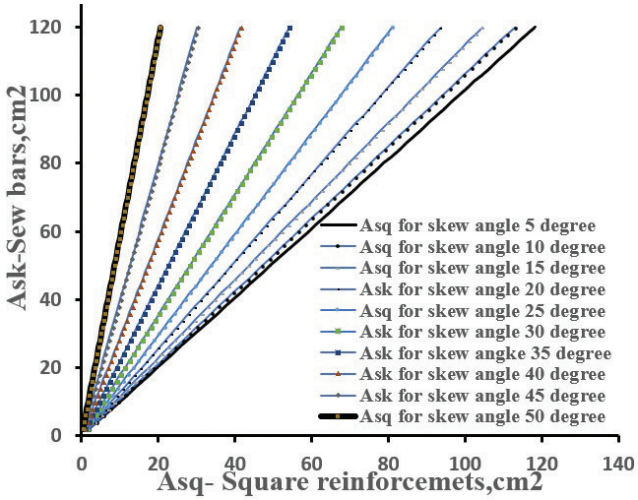
STEP:3 (LOADS ANALYSIS)
1) DL BM= W_d X L_{efs} $^2/_8$
2) LL BM = W(L_{efs})/8 for IRS loading
3) Shear I at obtuse corner due to DL = (1.3 to 1.55) x $R_{DL-obtuse}$
4)Shear II = LL reaction (R_{LL}) due to IRS loading
5) Torsional moments by WOOD ARMER Eqns.
6) Dist./secondary bars shall be as per clause15.9.4.2 of IRS-CBC-

STEP:4 (Designing Reinforcement)
1)Flexural steel is arrived using equations $M_u = (0.87 \times f_y) \times A_S \times Z$,$M_U = (0.15 \times f_{ck}) \times b \times d^2$ As per clauses 15.4.2.2 of IRS -CBC-2014
2) Flexural $\left[A_{st-square} = \sum(A_{st-skew} \text{ X } \cos^4(\theta))\right]$ & detailing as per clauses 15.9.8.2.1,15.9.4,15.9.8.2.1and15.9.10 of IRS-CBC-2014 3) Dist./secondary bars shall be as per clause15.9.4.2 of IRS_CBC-2014. 4) Shear & torsional bars shall be as per clause 15.4.3.2 and 15.4.4.3.1 of IRS-CBC-2014.

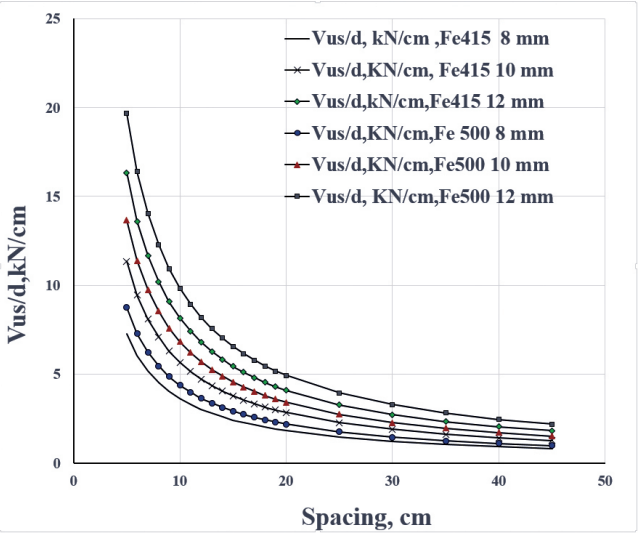
STEP:5 (Corner reinforcement at obtuse corner)
1) Main bars at double spacing over $\left(\frac{L_{skew}}{4} \times \frac{L_{skew}}{4}\right)$ area at corners in orthogonal directions to both sides at top and bottom as shown in MOST-SD_151-176 and BD-10-13, 1974.Drawings for skew slab clause 15.9.4.3 of IRS-CBC-2014 and as in IRS clause.



8.a. Moment of Resistance of slab per m width for P_t equal to 0.2,0.4,0.6,0.8 &1.0. for a slab with M30 and F_e500



8.b Area of rebars along square span (Asq)



$\frac{V_{us}}{d}$, kn/cm vs. Spacing for 8,10 mm and 12 mm bars of Fe415 and Fe500.

Fig. 8 Moment of Resistance of slab per m width for P_t,Area of rebars along square span and Shear resistance.

3. Arrangement of Reinforcement:

Three types of arrangement of reinforcement in are shown in Fig.9, Fig.10 and 9.11 respectively. Reinforcement at top of acute angle corners are provided to prevent cracks due to lifting of the acute angle corners.

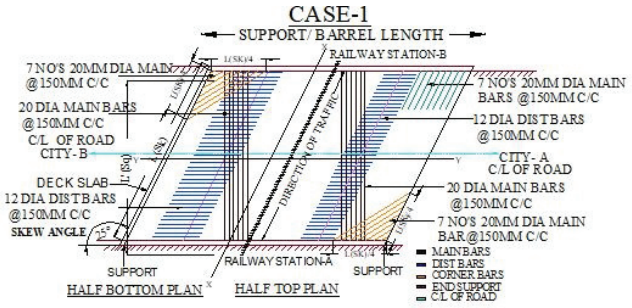


Fig.9. Reinforcement detail of Skew deck Slab (Main Reinforcement perpendicular to support-IRS)

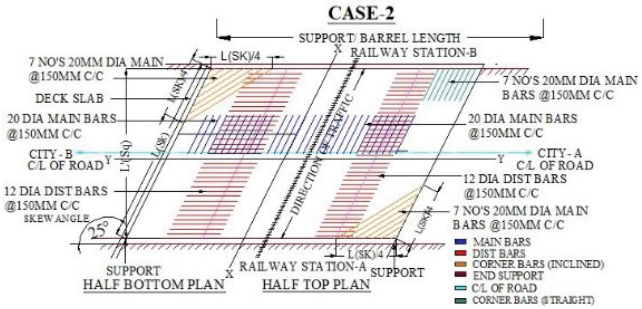


Fig.10. Reinforcement detail of Skew deck Slab (K. L. RAO) (Main reinforcement parallel to traffic)

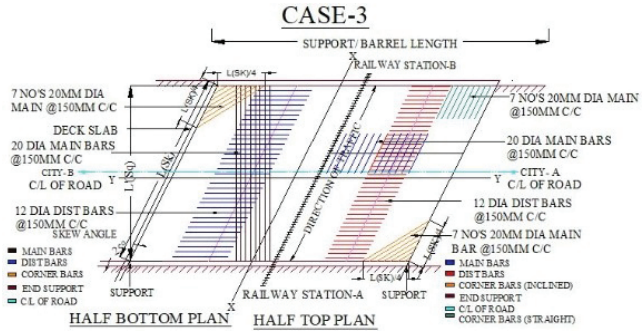


Fig.11 Reinforcement Details of Skew Slab (Main Reinforcement perpendicular to support-IRC)

The area of reinforcement provided perpendicular to the support is less than the same provided parallel to the road/track direction.

Table 3 Details of Few Skew Slab Bridges (IRS loadings) based on limit state method for 25t loding 2008

Clear Span (m)	Skew angle ,degrees	Slab thickness (mm)	Bottom Reinforcement			Top Reinforcement		
			Main bars (Astb)	Distributors (Astd)	Shear reinforcement	Top Main bars (Astt)	Distributors (Astd)	Corner bars at top and bottom (Astc)
4.57	10	450	25 ϕ 200	12 ϕ 200	12 ϕ 200x 200	12 ϕ 200	12 ϕ 200	25 ϕ 400
	20	500	25 ϕ 190	12 ϕ 200	12 ϕ 190x200	12 ϕ 190	12 ϕ 200	25 ϕ 380
	30	550	25 ϕ 160	12 ϕ 200	12 ϕ 160x 200	12 ϕ 160	12 ϕ 200	25 ϕ 320
	40	600	25 ϕ 120	12 ϕ 200	12 ϕ 120x 200	12 ϕ 120	12 ϕ 200	25 ϕ 240
	50	650	25 ϕ 100	12 ϕ 200	12 ϕ 100x 200	12 ϕ 100	12 ϕ 200	25 ϕ 200
6.10	10	600	32 ϕ 240	12 ϕ 200	12 ϕ 240x 200	12 ϕ 240	12 ϕ 200	32 ϕ 480
	20	625	32 ϕ 210	12 ϕ 200	12 ϕ 210x 200	12 ϕ 210	12 ϕ 200	32 ϕ 420
	30	650	32 ϕ 170	12 ϕ 200	12 ϕ 170x 200	12 ϕ 170	12 ϕ 200	32 ϕ 340
	40	675	32 ϕ 130	12 ϕ 200	12 ϕ 130x 200	12 ϕ 130	12 ϕ 200	32 ϕ 260
	50	700	32 ϕ 100	12 ϕ 200	12 ϕ 100x 200	12 ϕ 100	12 ϕ 200	32 ϕ 200
9.15	10	900	32 ϕ 130	12 ϕ 200	12 ϕ 130x 200	12 ϕ 130	12 ϕ 200	32 ϕ 260
	20	950	32 ϕ 115	12 ϕ 200	12 ϕ 115x 200	12 ϕ 115	12 ϕ 200	32 ϕ 230
	30	925	Girders with Deck Slab are suitable					
	40	950	Girders with Deck Slab are suitable					
	50	975	Girders with Deck Slab are suitable					

RC details of Few Skew Slab Bridges (IRS loadings) based on limit state method for 25t loading 2008 are given in Table 3.As the grade of concrete increases, the percentage of tension steel for skew decreases as shown in Fig.12. The Fig.16 indicates that percentage of tension steel for skew increase for same grade of concrete and steel under different skew angles.

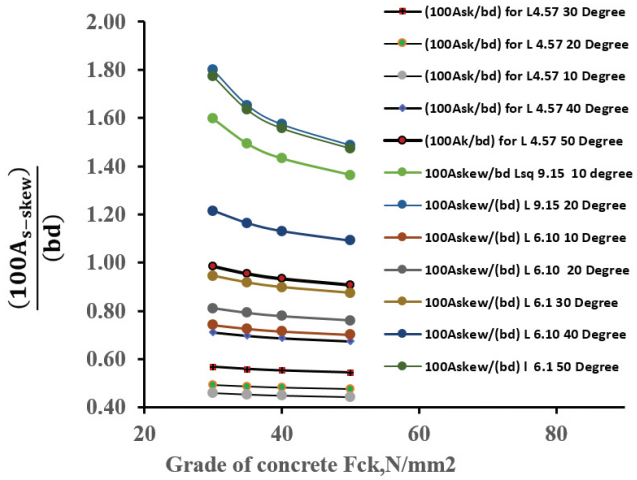


Fig.12 Variation of percentage of tension steel $\frac{(100A_{s\text{-}skew})}{(bd)}$ with grade of concrete F_{ck} for various skew angles and skew spans.

It is believed that the load travels to the support in proportion to the rigidity of the various paths and since the thickness of the slab is the same everywhere, the rigidity will be maximum along shortest span i.e. along the span normal to the faces of the piers or abutments. In Fig. 13, though the span of the deck is the length BC or DE, the slab will span along AB or CD being the shortest distance between the supports. Therefore, the plane of maximum stresses in a skew slab are not parallel to the centre line of roadway and the deflection of such slab produces a warped surface.

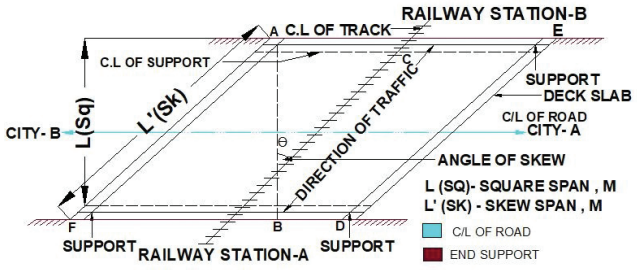


Fig. 13 Plan of Skew Slab

The effect of skew in deck slabs having skew angles up to 20º, is not so significant and in designing such bridges, the length parallel to the centre line of the roadway is taken as the span. The thickness of the slab and the reinforcement are calculated with this span lengths and the reinforcement are placed parallel to the centre line of the roadway. The distribution bars are, however, placed parallel to the supports as usual. When the skew angle varies from 20º to 50º, the skew effect becomes significant and the slab tends to span normal to the supports. In such cases, the slab thickness is determined with shortest span but the reinforcement worked out on the basis of shortest span are multiplied by [sec(θ)]^2, (θ being the skew angle) and are placed parallel to the roadway as shown in Fig. 14a, the distribution bars being placed parallel to the supports as usual.

It is also a common practice to place the reinforcement perpendicular to the support when the skew angle lies between 20º to 50º. The thickness and the reinforcement are determined with span normal to the support but since in placing the reinforcement perpendicular to the supports, the corner reinforcement within the area ABF or CDE (Fig. 13) do not get any support on one side to rest on, the slab below the footpath (for bridge with footpath) or below the road kerb (for bridge without footpath) shall be provided with extra reinforcement to act as concealed beam.

Alternatively, parapet girders as illustrated in Fig. 14b and 14c may also be provided along the edge of the slab. Such parapet girders are made flush with the bottom of the slab and extended above the slab to the required height to form the solid parapet. This sort of deck requires less quantity of steel in slabs but parapet girders need additional cost.

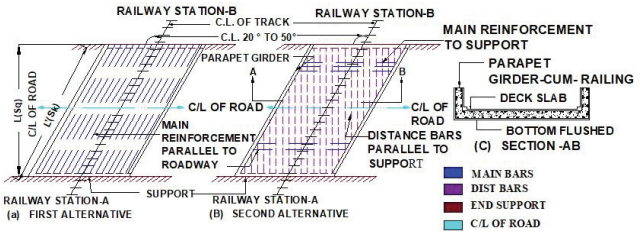


Fig. 14 Arrangement of Teinforcement in slab with skew angle of (20º-50º).

For skew bridges angles more than 50º , girders should be used even though the spans are comparatively less. Where the width of the bridge is not much, the girders may be placed parallel to the roadway and the slab thickness and the reinforcement may be designed with the spacing of the girders as the span.

The reinforcement are placed normal to the girders (Fig. 15a). In wider multi-lane skew crossings with large skew angles, however, it is preferable to use the girders at right angles to the supports. In such cases again, the triangular portions need parapet girders to support one end of the girders. The reinforcement are used normal to the girders as shown in Fig. 15b.

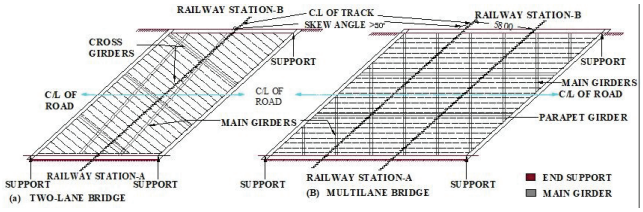


Fig.15 Girder Bridges with Skew Angle greater than 50°

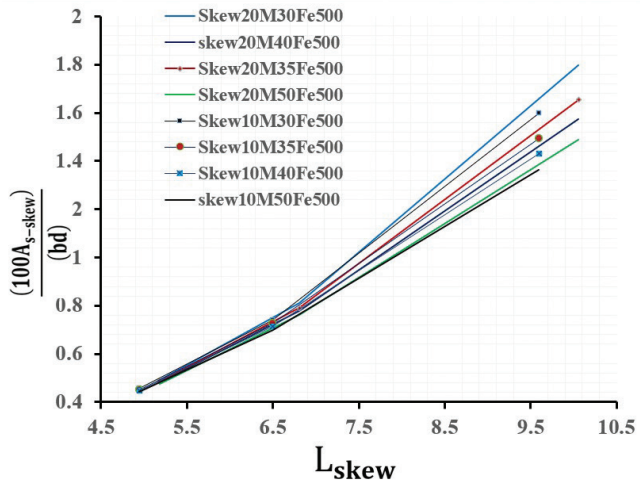


Fig. 16 Variation of percentage of tension steel $\frac{(100A_{s\text{-}skew})}{(bd)}$ for skew spans (L_{skew})

Table 4 Table Percentage of tension steel for slabs with various skew spans, skew angles and Grade of concrete with grade of steel F_c500

Table Percentage of tension steel for slabs with various skew spans, skew angles and grade of concrete for Grade of steel Fe500					
Sl. No	Lskew, m	Fck,N/mm2	100 Askew / (bd)		
			30°	40°	50°
1	4.87	30	0.5665	0.7109	0.9847
2	4.87	35	0.5576	0.6963	0.9539
3	4.87	40	0.5514	0.6862	0.9333
4	4.87	50	0.5431	0.673	0.9074
5	6.4	30	0.9441	1.2147	1.7751
6	6.4	35	0.9162	1.1634	1.6352
7	6.4	40	0.8974	1.1307	1.5587
8	6.4	50	0.8737	1.0909	1.4745

4. Creep Effect:

4.a) The longer diagonal of the skew deck connecting the acute angle corners elongate due to the load transference on the supports resulting in creep of the acute angle comers as illustrated in Fig. 17a.

4.b) This creeping effect of the deck slab induces tension along longer diagonal and tension cracks and lifting may appear if sufficient steel is not provided at the top and bottom in both direction to cater for this tensile stress (Fig. 17b).

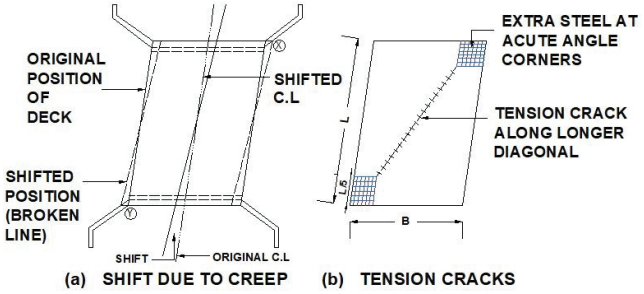


Fig. 17 Creep in Skew Bridges.

4.c) In order to avoid the damage to wing walls at X and Y due to creep effect and movement of the deck, it has been recommended to provide fixed bearings over abutments.

4.d) The deck slab connected to the abutment cap /pier cap / with dowel bars or providing some raised blocks or buffers over piers seems to be the effective method of preventing against the creep effect over piers. This arrangement is shown in Fig. 18.

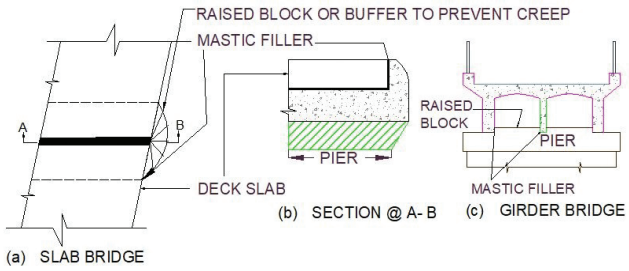


Fig.18 Prevention of Creep

5.Layout of Bearings:

5.i) Providing fixed bearings on both the abutments up to 15.0 m span for a single span bridge for preventing the moment of deck due to creep is essential.

5.ii) Adopting the fixed bearings over the abutments and free or fixed bearings over the piers of multi-span simply supported bridges, or with two free bearings on one pier and be oriented at right angles to the girders is effective. The typical layouts of the bearings in skew bridges are indicated in Fig. 19.

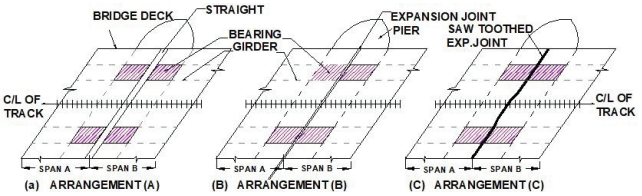


Fig. 19 Layout of Bearing and Expansion Joints in Skew Girders

6.Layout of Expansion Joints :

6.a)The Fig.19a shows straight expansion joint, which requires more pier width and unused space between piers of adjacent spans.

6.b) By making a notch over the affected portions of the girders, the deck slab rests on these notches to reduce the width of pier and bring the bearing closer. These type is shown Fig. 19b.

6.c) A saw-toothed type of expansion joint is adopted here with a view to avoid the sort of arrangements necessary for the second one. The width of pier and location of the bearings for this type shown in Fig. 19c

6.d). Suitable joint filler like lead sheet or tarred paper may be inserted between the girders and the deck slab to allow movement of the expansion joint.

7. Details of Few Skew Slab Bridges (IRC loadings):

7.a). The skew RC details are available for the square spans (i.e.4.37 m, 5.37 m, 6.37 m and 8.37 m with skew angles of 15°, 30°, 45° and 60° for each span).

7.b). The IRC design is based on M20 grade concrete and S415 grade steel using working stress method. Salient features of these skew slab bridges are given in Table 5. For further details, the standard plans under reference may be reviewed.

Table 5. Salient features of skew slab bridges (IRC loadings)

Clear Span (m)	Skew angle degrees	Slab thick-ness (mm)	Bottom Reinforcement			Top Reinforcement	
			Main bars	Transverse bars	Edge bars at each edge	Transverse bars	Corner bars
5	15	465	20 ϕ 130	10 ϕ 90	20 ϕ 140	10 ϕ 300	16 ϕ 300
	30	465	20 ϕ 130	10 ϕ 90	20 ϕ 130	10 ϕ 300	16 ϕ 300
	45	465	20 ϕ 130	10 ϕ 90	20 ϕ 120	10 ϕ 200	16 ϕ 190
	60	465	20 ϕ 120	10 ϕ 110	20 ϕ 120	10 ϕ 180	16 ϕ 100
6	15	540	20 ϕ 115	10 ϕ 100	20 ϕ 110	10 ϕ 300	16 ϕ 300
	30	540	20 ϕ 115	10 ϕ 100	20 ϕ 110	10 ϕ 260	16 ϕ 300
	45	540	20 ϕ 115	10 ϕ 100	20 ϕ 110	10 ϕ 200	16 ϕ 170
	60	540	20 ϕ 95	10 ϕ 160	20 ϕ 110	10 ϕ 160	16 ϕ 90
8	15	700	25 ϕ 150	10 ϕ 90	25 ϕ 150	10 ϕ 260	20 ϕ 300
	30	700	25 ϕ 150	10 ϕ 110	25 ϕ 140	10 ϕ 230	20 ϕ 300
	45	700	25 ϕ 150	10 ϕ 150	25 ϕ 130	10 ϕ 160	20 ϕ 180
	60	700	25 ϕ 150	10 ϕ 180	25 ϕ 120	10 ϕ 90	20 ϕ 90

7.c) For the square span of range between 4.57 m to 9.15 m, skew angle ranging from 10° to 50°, grade of concrete varying from M30 to M50, overall depth varing from 450 mm to 700 mm with grade of steel for Fe500 under the IRS 25t 2008 loading standard

, 100As-skew/bd increases with the increase of Lsq/D as shown in Fig.20.

The trend equation is given below.

$$\frac{L_{sq}}{D} = 0.993 \times \left(\frac{(100 \times A_{s\text{-}skew})}{(b \times d)} \right) + 8.821$$

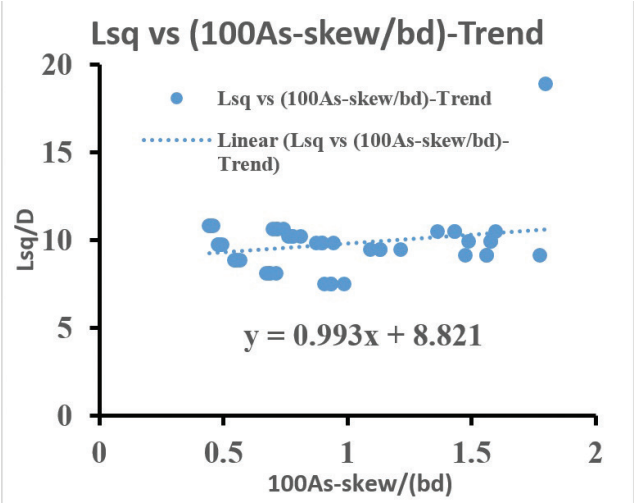


Fig. 20. Variation of $\frac{(100A_{s\text{-}skew})}{(bd)}$ with $\frac{L_{sq}}{D}$

8. Conclusions.

a. For skew bridges angles more than 50º, proper girders with deck slabs are feasible and suitable even though the spans are comparatively less

b. Reinforcement detail of Skew deck Slab with main Reinforcement perpendicular to support and distribution bars parallel to support are the effective arrangement of reinforcement detailing for (20°)<θ<(50°).

c. For (θ)<(20^°) & for large skew angle (θ) with low ratio of skew breadth to skew span $\left[\frac{\text{Barrel length}}{L_{skew}}\right]$ Providing reinforcement in directions perpendicular and parallel to the free edges are effective.

d. Adopting proper layout of expansion joints, bearings and anti-creep mechanism ensures the efficient functioning of skew slabs.

e/ Wood Armer equations are used to arrive for accurate design moments incorporating possible twisting moments resulting from the effect of skew based on plate element theory for IRC loadings.

f. The percentage of skew reinforcement increases for the increase in skew span for all skew angles, under the same grade of concrete and steel.

g. The percentage of skew reinforcement decreases for the increase in grade of concrete for all skew span and skew angles.

h. Increase in the ratio of square span to overall depth of slab results in the increase of percentage of tension steel for the cross section of slab.

j. Salient features of skew slab bridges (IRC loadings) are useful to assess the dimension and quantity of materials

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Stability Equations for Embankment Design

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ABSTRACT

In case of embankments, slope stability is governed by the ratio of effective cohesion of the fill to the overburden pressure and its angle of internal friction. For determining the slope stability, outcomes of research work carried out by R J Chandler and T A Peiris is widely used. One has to carryout tedious calculations, for obtaining suitable shear strength parameters for the fill soil, required to achieve desired factor of safety. Using Computer programming, stability envelope equations were determined for FOS =1.4 & 1.6, considering side slopes of 2H :1V and 3H :1V. Using these equations one can determine minimum essential value of shear strength parameters for a stable embankment.

1. Introduction

On Indian Railways embankments were designed as per "Comprehensive Guidelines and Specifications for Railway Formation a.k.a. specification No. RDSO/2020/GE: IRS-0004". Chapter No. 5 of this specification illustrates an iterative method to find the factor of safety, based on soil parameters. This method is developed by RDSO, based on the Research works of Bishop's, Morgenstern, R J Chandler and T A Peiris. Results of these research works were available in the form of tables for various side slopes (H :V), angle of internal friction (Φ) and ratio of effective cohesion to overburden pressure (C/Y.H). Using stability coefficient equation, Factor of safety should be determined for a given set of parameters. However it is not possible to find the combination of these parameters which gives a desired Factor of Safety. RDSO specifies a Factor of safety of 1.6 for embankment height up to 4m and 1.4 for embankment height exceeding 1.6, by restricting the steepness of side slopes to 2H : 1V. However it is not possible to check the critical combination of C/Y.H and Φ values for a given side slope which gives desired Factor of safety. Therefore in this analytical research work, with the aid of computer programming, envelopes were developed for desired factor of safety against slope stability, by considering two side slopes, 2H :1V and 3H :1V.

2. Literature Review :

In order to simplify the procedure for determining the factor of safety with respect to slope stability, R J Chandler and T A Pieris carried out research work. Outcomes of their Research work consists of total 19 number of tables. These tables were derived by considering cohesion to overburden ratios and angle of internal friction values ranging between 20 to 40 degrees, for three different depth factors. From these tables one can determine factor of safety based on stability coefficients applicable for given input parameters. However by making use of this method, it is not possible to obtain a quick clear picture regarding the combination of parameters, which can achieve required factor of safety.

As per RDSO guidelines, maximum steepness of side slope should be 2H : 1V. Factor of safety to be achieved for stability is 1.4 for bank height exceeding 4m and 1.6 for bank heights up to 4m.

For ensuring the embankment side slope stability, RDSO suggested a method similar to the one which is proposed by RJ Chandler and TA Peiris.

3. Methodology

In Indian Scenario adopting a side slope ranging from 2H : 1V to 3H : 1V can be justified from techno economic considerations. Therefore in this research work, envelopes were developed only for these side slopes, by considering the pore water pressure ratio applicable for newly constructed embankment condition. A envelope obtained by considering the possible safe combination of C/Y.H and Φ values for required F.O.S value is used to define a demarcation between unsafe and safe combinations of values.

Linear equations were derived for stability envelopes, by idealization of non linear curve to a suitable straight line.

4. Results and Discussions :

1. Using the valuable outcomes from earlier research of R J Chandler and T.A. Peiris , two stability envelopes were developed with the aid of computer program.

2. In this research work, factor of safety of 1.4 and 1.6 are considered for developing stability envelopes based on Pore Water Pressure Ratio (PWPR) of 0.25, applicable for newly constructed embankment condition.

3. From Figure 1 and 2, it can be seen that the interrelation between C/Y.H and Ǿ can be presented in the form of idealized linear equation of the form " y = m.x + c " as follows. Any set of values satisfying the following equations can be considered as safe bound solution for given factor of safety.

4. The idealized straight line falls on conservative side, thus giving safe bound solutions.

5. All those combinations falling on left hand side of the stability envelope will be having lower FOS, whereas all those combinations falling on right hand side of the stability envelope will be having higher FOS.

Refer : Figure 1 for Side Slope = 2 : 1 with PWPR = 0.25	
FOS	Equation Form
1.4	Ǿ = -284.13 [C/Y.H] + 43.41
1.6	Ǿ = -242.77 [C/Y.H] + 45.83
For Ǿ values between 20 to 40 degrees	

Refer : Figure 2 for Side Slope = 3 : 1 with PWPR = 0.25	
FOS	Equation Form
1.4	Ǿ = -307 [C/YH] + 31.29
1.6	Ǿ = -255.48 [C/YH] + 34.82
For Ǿ values between 20 to 40 degrees	

Illustrative Example :

Data :

a) Side Slope = 2 : 1

b) Embankment height, H = 4m

c) Required FOS = 1.6

d) ϕ = 30degrees.

e) Y = 20kN/m³

Now the Minimum required Cohesion for safety of the side slope can be derived from the following equation.

Ǿ = -242.77 [C/Y.H] + 45.83

30 = -242.77* [C/Y.H] + 45.83

[C/Y.H] = (30-45.83)/(-242.77)

[C/Y.H] = 0.065

C = 0.065 * (Y.H)

C = 0.065 * 20 * 4 = 5.216 kPa.

5. Conclusions.

1. For ensuring slope stability, stability envelope concept is an easy, simple, reliable and efficient method, instead of adopting the manual calculation method involving iterative procedure.

2. Precisely developed stability envelopes are viable fool proofing technique, while judging slope stability.

3. Feasibility of construction of embankment for a given site conditions can be quickly ascertained from idealized stability envelope equations.

6 . Future Scope of this Research work.

Author is interested in developing several stability graphs, if Geo technical Authorities of Indian Railway are willing to adopt this technique.

7. References :

1. Comprehensive Guidelines And Specifications For Railway Formation. Specification No. RDSO/2020/GE: IRS-0004

2. “Further extensions to the Bishop & Morgenstern slope stability charts.”, RJ Chandler and TA Peiris. GROUND ENGINEERING MAY 1989

FIGURE 1 : SAFETY ENVELOPES FOR SIDE SLOPE OF 2H:1V, FOR Φ VALUES BETWEEN 20 TO 40 DEGREE

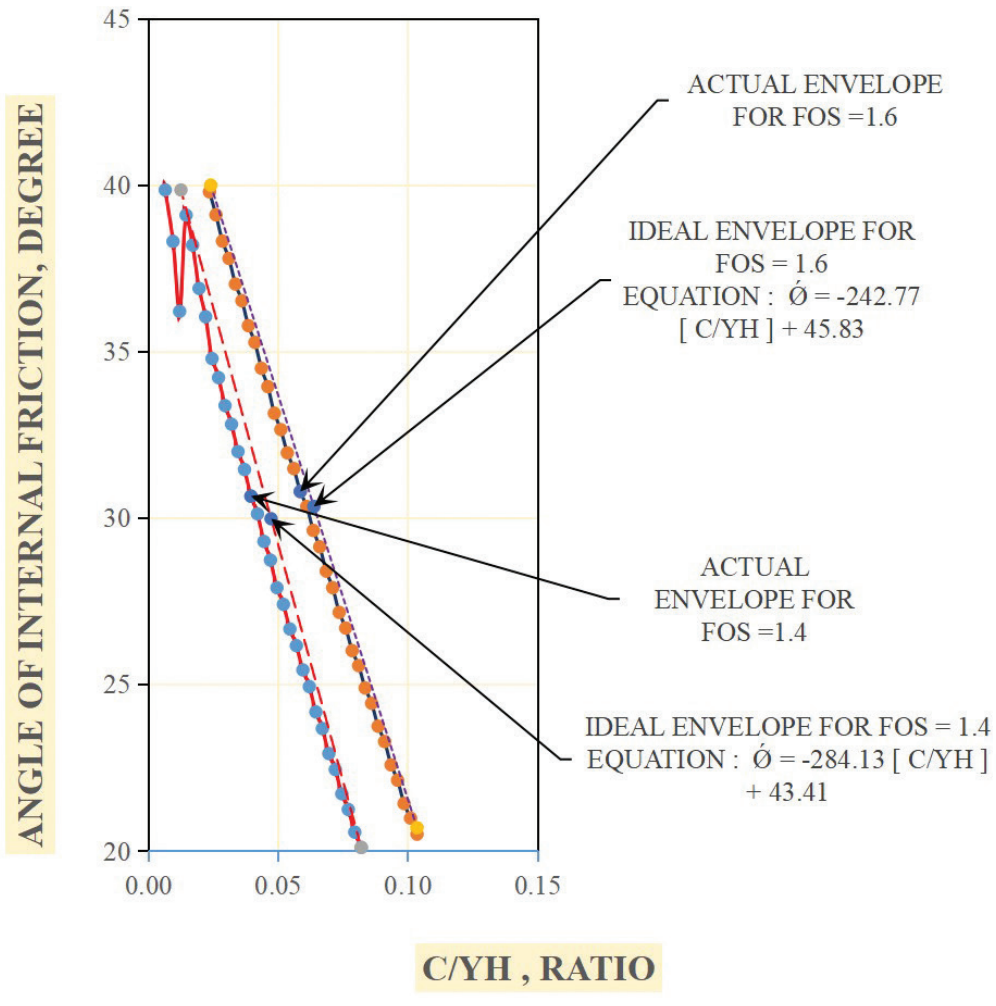
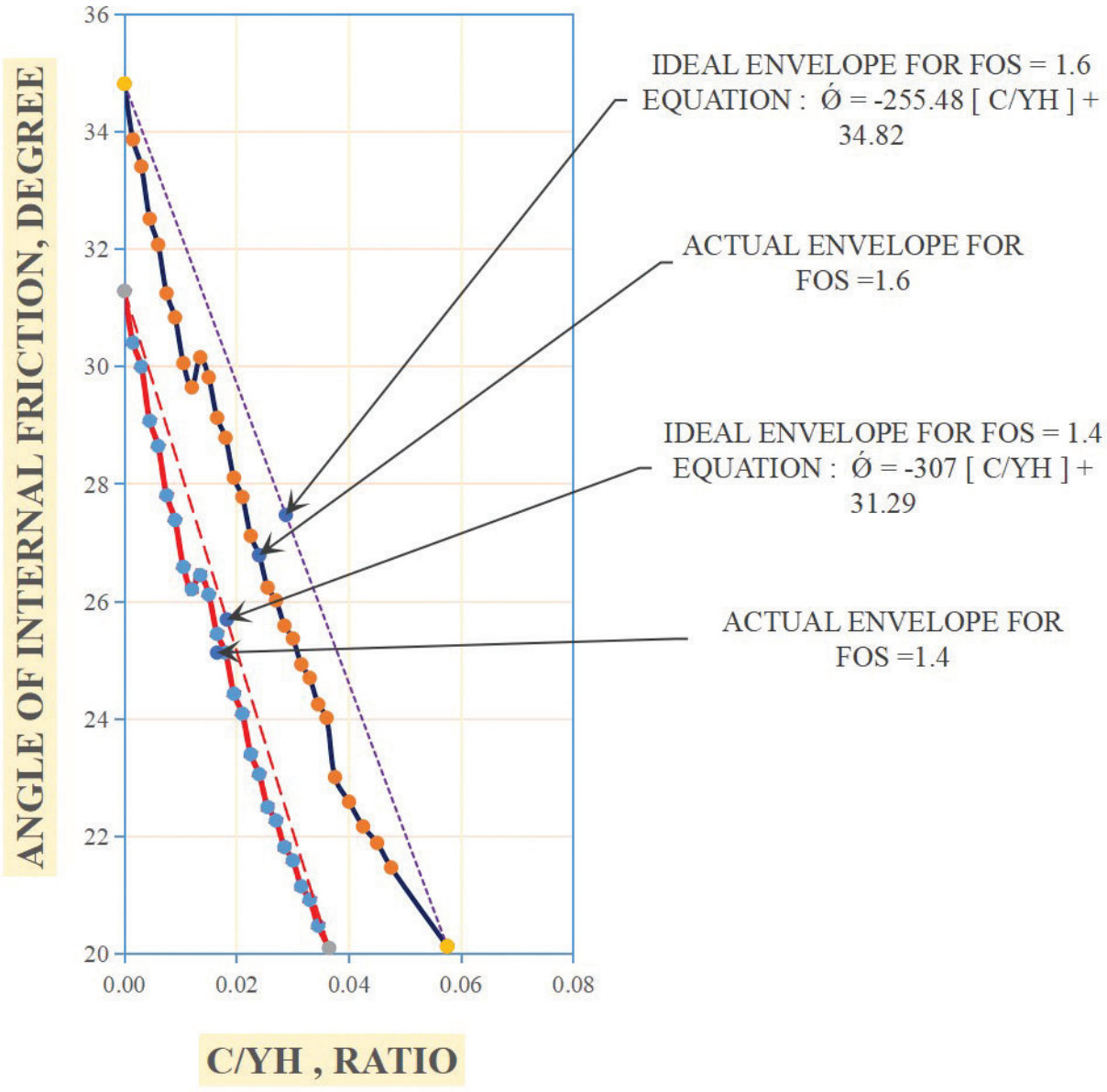


FIGURE 2 : SAFETY ENVELOPES FOR SIDE SLOPE OF 3H:1V, FOR Φ VALUES BETWEEN 20 TO 40 DEGREE



Statement of Courses IRICEN CoC-2024

COURSE NO	COURSE NAME	FROM	TO	DURATION	TIMINGS	ELIGIBILITY
JANUARY						
24401	Curve, turnouts and layout calculations	01.01.24	05.01.24	1 W	Campus	All officers
24402	Concrete technology and durability	01.01.24	05.01.24	1 W	Campus	All officers
24211	Webinar: Facilities for Divyangjan	05.01.24	05.01.24	1 Day	Online	All officers
24403	Special course for Gati Shakti Unit	08.01.24	12.01.24	1 W	Campus	XEN/Dy.CPM/ CPM/GSU
24212	Webinar	12.01.24	12.01.24	1 Day	Online	All officers
24001	IRMS (Civil)(Phase-I)	15.01.24	05.04.24	12 W	Campus	IRMS(Civil) 2022(Exam Batch) (P)
24501	Special course for Sri Lanka Railway through IRCON	15.01.24	27.01.24	2 W	Campus	Sri Lanka Railway Personnel (P.Way Inspectors & Engineers)
24213	Webinar	25.01.24	25.01.24	1 Day	Online	All officers
24301	Workshop on Station development	29.01.24	31.01.24	3 Days	Campus	Dy.CE/CE/Station development
FEBRUARY						
24302	CBE Seminar	01.02.24	02.02.24	2 Days	Campus	All CBE of Railways
24502	Special course for Sri Lanka Railway through IRCON	05.02.24	16.02.24	2 W	Campus	Sri Lanka Railway Personnel (P.Way Inspectors & Engineers)
24214	Webinar	09.02.24	09.02.24	1 Day	Online	All officers
24101	Integrated	19.02.24	10.05.24	12 W	Campus	Gr. B officers
24215	Webinar	20.02.24	20.02.24	1 Day	Online	All officers
24303	CTE Seminar	22.02.24	23.02.24	2 Days	Campus	All CTE of Railways
24451	MIDAS	26.02.24	01.03.24	1 W	Campus	Officers and Design Assistants
24503	Special course for Sri Lanka Railway through IRCON	26.02.24	08.03.24	2 W	Campus	Sri Lanka Railway Personnel (P.Way Inspectors & Engineers)
MARCH						
24404	Contract & Arbitration, IRWCMS	04.03.24	15.03.24	2 W	Campus	All officers
24216	Webinar	08.03.24	08.03.24	1 Day	Online	All officers
24405	Bridge Design	18.03.24	05.04.24	3 W	Campus	All officers
24504	Special course for Sri Lanka Railway through IRCON	18.03.24	29.03.24	2 W	Campus	Sri Lanka Railway Personnel (P.Way Inspectors & Engineers)
24217	Webinar	22.03.24	22.03.24	1 Day	Online	All officers
24406	Project Management Tools & Software	25.03.24	29.03.24	1 W	Campus	All officers
APRIL						
24218	Webinar	05.04.24	05.04.24	1 Day	Online	All officers

24201	Sr.Prof.P.Way	08.04.24	03.05.24	4 W	Campus	JAG, Selection Grade, SAG Officers
24407	USFD & Rail Grinding	08.04.24	12.04.24	1 W	Campus	All officers
24408	Curve, turnouts and layout calculations	15.04.24	19.04.24	1 W	Campus	All officers
24219	Webinar	19.04.24	19.04.24	1 Day	Online	All officers
24409	Mechanised maintenance & Track tolerances and Track Monitoring	22.04.24	26.04.24	1 W	Campus	All officers
24505	Special course for Sri Lanka Railway through IRCON	22.04.24	03.05.24	2 W	Campus	Sri Lanka Railway Personnel (P.Way Inspectors & Engineers)
24410	Derailment Investigation	29.04.24	03.05.24	1 W	Campus	All officers
MAY						
24220	Webinar	03.05.24	03.05.24	1 Day	Online	All officers
24011	Appreciation course for IRMS (other than civil)	06.05.24	17.05.24	2 W	Campus	IRMS 2022(Exam Batch)(P) (Other than Civil)
24411	LWR & Yard Layout	06.05.24	10.05.24	1 W	Campus	All officers
24102	Integrated	13.05.24	02.08.24	12 W	Campus	Gr. B officers
24506	Special course for Sri Lanka Railway through IRCON	13.05.24	24.05.24	2 W	Campus	Sri Lanka Railway Personnel (Building Inspectors & Bridge Inspectors)
24221	Webinar	17.05.24	17.05.24	1 Day	Online	All officers
24304	Workshop on Station development	20.05.24	22.05.24	3 Days	Campus	Dy.CE/CE/Station development
24305	PCE Seminar	23.05.24	24.05.24	2 Days	Campus	All PCE of Railways
24412	Special course for Gati Shakti Unit	27.05.24	31.05.24	1 W	Campus	XEN/Dy.CPM/ CPM/GSU
24452	Bentley Open rail	27.05.24	31.05.24	1 W	Campus	All officers
JUNE						
24413	Modern surveying	03.06.24	07.06.24	1 W	Campus	All officers
24507	Special course for Sri Lanka Railway through IRCON	03.06.24	14.06.24	2 W	Campus	Sri Lanka Railway Personnel (Building Inspectors & Bridge Inspectors)
24222	Webinar	07.06.24	07.06.24	1 Day	Online	All officers
24414	Bridge Planning and construction	10.06.24	14.06.24	1 W	Campus	All officers
24415	Formation construction	17.06.24	21.06.24	1 W	Campus	All officers
24012	Course for MES Eng.	17.06.24	21.06.24	1 W	Campus	MES Engineers
24223	Webinar	21.06.24	21.06.24	1 Day	Online	All officers
24416	Concrete technology and durability	24.06.24	28.06.24	1 W	Campus	All officers
24508	Special course for Sri Lanka Railway through IRCON	24.06.24	05.07.24	2 W	Campus	Sri Lanka Railway Personnel (Building Inspectors & Bridge Inspectors)
24306	Workshop for facilities related to Divyangjan	24.06.24	26.06.24	3 Days	Campus	All officers

24307	CPD/CE/Station Development Seminar	27.06.24	28.06.24	2 Days	Campus	All CPD/ CE/Station Development of Railways
JULY						
24417	LWR & Yard Layout	01.07.24	05.07.24	1 W	Campus	All officers
24224	Webinar	05.07.24	05.07.24	1 Day	Online	All officers
24418	USFD & Rail Grinding	08.07.27	12.07.24	1 W	Campus	All officers
24419	Bridge inspection and maintenance	08.07.27	12.07.24	1 W	Campus	All officers
24420	Concrete technology and PSC construction	15.07.24	19.07.24	1 W	Campus	All officers
24509	Special course for Sri Lanka Railway through IRCON	15.07.24	26.07.24	2 W	Campus	Sri Lanka Railway Personnel (Building Inspectors & Bridge Inspectors)
24225	Webinar	19.07.24	19.07.24	1 Day	Online	All officers
24510	PSU Course Slot	22.07.24	02.08.24	2 W	Campus	
24421	Mechanised maintenance & Track tolerances and Track Monitoring	29.07.24	02.08.24	1 W	Campus	All officers
AUGUST						
24226	Webinar	02.08.24	02.08.24	1 Day	Online	All officers
24422	Derailment Investigation	05.08.24	09.08.24	1 W	Campus	All officers
24103	Integrated	05.08.24	25.10.24	12 W	Campus	Gr. B officers
24423	Tunneling	05.08.24	16.08.24	2 W	Campus	All officers
24424	LWR & Yard Layout	12.08.24	16.08.24	1 W	Campus	All officers
24227	Webinar	16.08.24	16.08.24	1 Day	Online	All officers
24453	MIDAS	19.08.24	23.08.24	1 W	Campus	Officers and Design Assistants
24308	Workshop on Station development	19.08.24	21.08.24	3 Days	Campus	Dy.CE/CE/Station development
24309	CAO(C) Seminar	22.08.24	23.08.24	2 Days	Campus	All CAO(C) of Railways
24425	Project Management Tools & Software	26.08.24	30.08.24	1 W	Campus	All officers
24511	PSU Course Slot	26.08.24	06.09.24	2 W	Campus	
24228	Webinar	30.08.24	30.08.24	1 Day	Online	All officers
SEPTEMBER						
24426	USFD & Rail Grinding	02.09.24	06.09.24	1 W	Campus	All officers
24202	Sr.Prof.Bridge	09.09.24	04.10.24	4 W	Campus	JAG, Selection Grade, SAG Officers
24427	Fabrication and inspection of steel girders	09.09.24	13.09.24	1 W	Campus	All officers
24428	Special course for Gati Shakti Unit	09.09.24	13.09.24	1 W	Campus	XEN/Dy.CPM/ CPM/GSU
24229	Webinar	13.09.24	13.09.24	1 Day	Online	All officers
24429	Bridge Planning and construction	16.09.24	20.09.24	1 W	Campus	All officers
24430	Concrete technology and durability	23.09.24	27.09.24	1 W	Campus	All officers
24230	Webinar	27.09.24	27.09.24	1 Day	Online	All officers
24431	Bridge inspection and maintenance	30.09.24	04.10.24	1 W	Campus	All officers

OCTOBER						
24432	Contract & Arbitration, IRWCMS	07.10.24	18.10.24	2 W	Campus	All officers
24454	STAADPRO	07.10.24	11.10.24	1 W	Campus	Officers & Design Assistants
24231	Webinar	11.10.24	11.10.24	1 Day	Online	All officers
24512	PSU Course Slot	14.10.24	25.10.24	2 W	Campus	
24433	USFD & Rail Grinding	21.10.24	25.10.24	1 W	Campus	All officers
24232	Webinar	25.10.24	25.10.24	1 Day	Online	All officers
NOVEMBER						
24002	IRMS (Civil)(Phase-II)	11.11.24	03.01.25	8 W	Campus	IRMS (Civil) 2022 (Exam Batch) (P)
24104	Integrated	11.11.24	31.01.25	12 W	Campus	Gr. B officers
24310	IRICEN Day	13.11.24	15.11.24	3 Days	Campus	IRSE 98 batch
24434	Formation construction	18.11.24	22.11.24	1 W	Campus	All officers
24233	Webinar	22.11.24	22.11.24	1 Day	Online	All officers
24435	LWR & Yard Layout	25.11.24	29.11.24	1 W	Campus	All officers
24311	Workshop on Station development	25.11.24	27.11.24	3 Days	Campus	Dy.CE/CE/Station development
24312	CE/TMC Seminar	28.11.24	29.11.24	2 Days	Campus	All CE/TMC of Railways
DECEMBER						
24436	Concrete technology and PSC construction	02.12.24	06.12.24	1 W	Campus	All officers
24234	Webinar	06.12.24	06.12.24	1 Day	Online	All officers
24437	Mechanised maintenance & Track tolerances and Track Monitoring	09.12.24	13.12.24	1 W	Campus	All officers
24438	Derailment Investigation	16.12.24	20.12.24	1 W	Campus	All officers
24439	Fabrication and inspection of steel girders	16.12.24	20.12.24	1 W	Campus	All officers
24235	Webinar	20.12.24	20.12.24	1 Day	Online	All officers
24455	AutoCAD/EDAS	30.12.24	03.01.25	1 W	Campus	All officers
24236	Webinar	31.12.24	31.12.24	1 Day	Online	All officers

SSTW Calendar of Courses -2024

COURSE NO	COURSE NAME	FROM	TO	DURATION	TIMINGS	ELIGIBILITY
JANUARY						
24801	Certificate course in Basics of Railway construction Project Supervision (Civil)	01.01.24	05.01.24	1 W	Campus	Engineers of PMS/ PSSA/ Contractors working on IR Projects/Works having completed Graduation/ Diploma in Civil Engineering
24601	Refresher Course (P.Way)	08.01.24	26.01.24	3 W	Campus	JE/SSE (P.Way)
24802	Derailment Investigation	08.01.24	12.01.24	1 W	Campus	JE/SSE (P.Way)
24602	Refresher Course (Bridges)	08.01.24	26.01.24	3 W	Campus	JE/SSE (Bridge)
24803	Building Planning, Construction & Maintenance	15.01.24	19.01.24	1 W	Campus	JE/SSE (Works)
24901	Special Course for executives of DFCCIL GR. I Ph-I	22.01.24	12.04.24	12 W	Campus	Executive of DFCCIL
24603	Refresher Course (USFD)	29.01.24	03.02.24	1 W	Campus	JE/SSE (USFD)
FEBRUARY						
24604	Refresher Course (P.Way)	05.02.24	23.02.24	3 W	Campus	JE/SSE (P.Way)
24804	Concrete Technology, PSC/ RCC for Bridges	05.02.24	09.02.24	1 W	Campus	JE/SSE (Works)
24805	Certificate course in Basics of Railway construction Project Supervision (Civil)	12.02.24	16.02.24	1 W	Campus	Engineers of PMS/ PSSA/ Contractors working on IR Projects/Works having completed Graduation/ Diploma in Civil Engineering
24806	Workshop for facilities related to Divyangjan	19.02.24	21.02.24	3 Days	Campus	JE/SSE (Works)
24807	P&C, Yard layout imrpovement and maintenance	26.02.24	01.03.24	1 W	Campus	JE/SSE (P.Way)
24808	IRWCMS & UDM	26.02.24	01.03.24	1 W	Campus	JE/SSE (Works)
MARCH						
24605	Refresher Course (P.Way)	04.03.24	22.03.24	3 W	Campus	JE/SSE (P.Way)
24809	Mechanised maintenance, Track tolerances & Track Monitoring and Rail Grinding	04.03.24	08.03.24	1 W	Campus	JE/SSE (P.Way)

24810	Certificate course in Basics of Railway construction Project Supervision (Civil)	11.03.24	15.03.24	1 W	Campus	Engineers of PMS/ PSSA/ Contractors working on IR Projects/Works having completed Graduation/ Diploma in Civil Engineering
24811	Special course for JE/ SSE(Drawing)	18.03.24	29.03.24	2 W	Campus	JE/SSE (Drawing)
24606	Refresher Course (USFD)	25.03.24	30.03.24	1 W	Campus	JE/SSE (USFD)
APRIL						
24607	Refresher Course (P.Way)	01.04.24	19.04.24	3 W	Campus	JE/SSE (P.Way)
24812	Fabrication and inspection of steel girders for FIUs	01.04.24	19.04.24	3 W	Campus	JE/SSE (Bridge & Works)
24813	Modern Surveying and Land Management	15.04.24	19.04.24	1 W	Campus	JE/SSE (Works)
24608	Refresher Course (Works)	22.04.24	03.05.24	2 W	Campus	JE/SSE (Works)
24902	Special Course for executives of DFCCIL GR. II Ph-I	22.04.24	12.07.24	12 W	Campus	Executive of DFCCIL
24814	Certificate course in Basics of Railway construction Project Supervision (Civil)	22.04.24	26.04.24	1 W	Campus	Engineers of PMS/ PSSA/ Contractors working on IR Projects/Works having completed Graduation/ Diploma in Civil Engineering
24815	TMS & UDM	29.04.24	03.05.24	1 W	Campus	JE/SSE (P.Way)
MAY						
24609	Refresher Course (P.Way)	06.05.24	24.05.24	3 W	Campus	JE/SSE (P.Way)
24816	CAD	06.05.24	10.05.24	1 W	Campus	All JEs/SSEs
24817	Formation construction	13.05.24	17.05.24	1 W	Campus	JE/SSE (Works)
24818	Certificate course in Basics of Railway construction Project Supervision (Civil)	20.05.24	24.05.24	1 W	Campus	Engineers of PMS/ PSSA/ Contractors working on IR Projects/Works having completed Graduation/ Diploma in Civil Engineering
24610	Refresher Course (USFD)	27.05.24	01.06.24	1 W	Campus	JE/SSE (USFD)
24819	Fabrication & Launching of steel Girder	27.05.24	31.05.24	1 W	Campus	JE/SSE (Bridge)
JUNE						
24611	Refresher Course (P.Way)	03.06.24	21.06.24	3 W	Campus	JE/SSE (P.Way)
24820	IRWCMS & UDM	03.06.24	07.06.24	1 W	Campus	JE/SSE (Works)

24821	Mechanised maintenance,Track tolerances & Track Monitoring and Rail Grinding	10.06.24	14.06.24	1 W	Campus	JE/SSE (P.Way)
24822	Concrete Technology, PSC/ RCC for Bridges	17.06.24	21.06.24	1 W	Campus	JE/SSE (Works)
24823	Derailment Investigation	24.06.24	28.06.24	1 W	Campus	JE/SSE (P.Way)
24824	Building Planning, Construction & Maintenance	24.06.24	28.06.24	1 W	Campus	JE/SSE (Works)
JULY						
24612	Refresher Course (P.Way)	01.07.24	19.07.24	3 W	Campus	JE/SSE (P.Way)
24825	CAD	01.07.24	05.07.24	1 W	Campus	All JEs/SSEs
24826	Special course for JE/ SSE(Drawing)	08.07.24	19.07.24	2 W	Campus	JE/SSE (Drawing)
24613	Refresher Course (Bridges)	15.07.24	02.08.24	3 W	Campus	JE/SSE (Bridge)
24614	Refresher Course (USFD)	22.07.24	27.07.24	1 W	Campus	JE/SSE (USFD)
24827	P&C, Yard layout imrpovement and maintenance	22.07.24	26.07.24	1 W	Campus	JE/SSE (P.Way)
24903	Special Course for executives of DFCCIL GR. I Ph-II	29.07.24	25.10.24	13 W	Campus	Executive of DFCCIL
AUGUST						
24615	Refresher Course (P.Way)	05.08.24	23.08.24	3 W	Campus	JE/SSE (P.Way)
24828	Certificate course in Basics of Railway construction Project Supervision (Civil)	26.08.24	30.08.24	1 W	Campus	Engineers of PMS/ PSSA/ Contractors working on IR Projects/Works having completed Graduation/ Diploma in Civil Engineering
SEPTEMBER						
24616	Refresher Course (P.Way)	02.09.24	20.09.24	3 W	Campus	JE/SSE (P.Way)
24829	Tunneling	09.09.24	13.09.24	1 W	Campus	JE/SSE (Works & Bridge)
24830	Modern Surveying and Land Management	23.09.24	27.09.24	1 W	Campus	JE/SSE (Works)
24617	Refresher Course (USFD)	30.09.24	05.10.24	1 W	Campus	JE/SSE (USFD)
OCTOBER						
24618	Refresher Course (P.Way)	07.10.24	25.10.24	3 W	Campus	JE/SSE (P.Way)
NOVEMBER						
24619	Refresher Course (P.Way)	11.11.24	29.11.24	3 W	Campus	JE/SSE (P.Way)
24831	Fabrication & Launching of steel Girder	18.11.24	22.11.24	1 W	Campus	JE/SSE (Bridge)
24904	Special Course for executives of DFCCIL GR. II Ph-II	18.11.24	14.02.25	13 W	Campus	Executive of DFCCIL

24832	Certificate course in Basics of Railway construction Project Supervision (Civil)	25.11.24	29.11.24	1 W	Campus	Engineers of PMS/ PSSA/ Contractors working on IR Projects/Works having completed Graduation/ Diploma in Civil Engineering
DECEMBER						
24620	Refresher Course (USFD)	02.12.24	07.12.24	1 W	Campus	JE/SSE (USFD)
24833	Derailment Investigation	02.12.24	06.12.24	1 W	Campus	JE/SSE (P.Way)
24834	P&C, Yard layout imrpovement and maintenance	09.12.24	13.12.24	1 W	Campus	JE/SSE (P.Way)
24835	Inspection and Maintenance of Bridge	09.12.24	13.12.24	1 W	Campus	JE/SSE (Bridge)
24621	Refresher Course (P.Way)	16.12.24	03.01.25	3 W	Campus	JE/SSE (P.Way)
24622	Refresher Course (Works)	16.12.24	27.12.24	2 W	Campus	JE/SSE (Works)
24836	Mechanised maintenance,Track tolerances & Track Monitoring and Rail Grinding	30.12.24	03.01.25	1 W	Campus	JE/SSE (P.Way)



Probationary Officers of IRSE 2018.



Probationary Officers of IRSE 2019.

Calendar Of Courses IRICEN 2024

Month & Year	Dec.2023				Jan.2024					Feb.2024				Mar.2024				Apr.2024					May 2024				June 2024			
Hostel Capacity	55	75	55	68	48	53	58	58	68	59	59	60	70	70	55	70	65	55	55	55	70	70	70	70	65	65	60	60	45	60
Date (Monday)	4	11	18	25	1	8	15	22	29	5	12	19	26	4	11	18	25	1	8	15	22	29	6	13	20	27	3	10	17	24
Institute holidays				25				26																						
IRMS (Civil)							24001 IRMS (Civil)(Phase-I)																24011 Appreciati						24012 MES	
Trainees							10	10	10	10	10	10	10	10	10	10	10	10					30	30						
Integrated courses	23105 Integrated											24101 Integrated													24102 Integrated					
Trainees	25	25	25	25	0	25	25	25	25	25	25	25	25	25	25	25	0	25	25	25	25	25	25	25	25	25	25	25	25	0
Sr.Prof. courses																			24201 Sr.Prof.P.Way											
Trainees																			15	15	15	15								
Track courses	23458		23459	23417	24401														24407	24408	24409	24410	24411							
Trainees	15		15	20	20														15	15	15	15	15							
Bridge Courses	23442		23443 Bridge - Construct		24402											24405 Bridge Design												24414		
Trainees	15		15	15	20											20	20	20										20		
Work courses						24403								24404 Contract			24406									24412	24413		24415	
Trainees						20								20	20		20									20	20		20	
Software courses													24451													24452				
Trainees													20													20				
Courses for PSU							24501 Special course for			24502 Special course for			24503 Special course for			24504 Special course for					24505 Special course for			24506 Special course for			24507 Special course for			24508 Special course for
Trainees							15	15		16	16		15	15		15	15				15	15		15	15		15	15		15
Courses for PSU				23504 Special course for Junior Managers of DFCCIL Gr. II Phase II																										
Trainees				8	8	8	8	8	8	8	8																			
Webinars					24211	24212		24213	24301	24214		24215		24216		24217		24218		24219		24220		24221	24304		24222		24223	24306
HAG/SAG Seminars		23307							24302			24303													24305					24307
Trainees		50							25			25													25					25
Misc.																														
Spare Capacity available	13	-7	13	0	20	15	10	10	0	9	9	8	-2	-2	13	-2	3	13	13	13	-2	-2	-2	-2	3	3	8	8	23	8

Month & Year	July 2024					Aug.2024				Sep.2024					Oct.2024				Nov.2024				Dec.2024					Jan.2025				
Hostel Capacity	55	60	56	61	65	65	60	70	65	65	50	55	55	55	65	65	65	0	0	60	55	75	50	55	50	35	55	25	25	25	25	0
Date (Monday)	1	8	15	22	29	5	12	19	26	2	9	16	23	30	7	14	21	28	4	11	18	25	2	9	16	23	30	6	13	20	27	3
Institute holidays							15							2				31														
IRMS (Civil)																		Diwali Holiday, No teaching activity		24002 IRMS (Civil)(Phase-II)												
Trainees																				10	10	10	10	10	10	10	10					
Integrated courses						24103 Integrated														24104 Integrated												
Trainees	25	25	25	25	25	25	25	25	25	25	0	25	25	25	25	25	25			25	25	25	25	25	0	25	25	25	25	25	25	
Sr.Prof. courses											24202 Sr.Prof.Bridge																					
Trainees											15	15	15	15																		
Track courses	24417	24418			24421	24422	24424			24426							24433					24435		24437	24438							
Trainees	15	20			20	20	15			20							20					15		20	20							
Bridge Courses		24419	24420								24427	24429	24430	24431									24436		24439							
Trainees		15	15								15	15	15	15									15		20							
Work courses						24423 Tunneling			24425		24428				24432 Contract						24434											
Trainees						20	20		20		20				20	20					20											
Software courses								24453							24454												24455					
Trainees								20							20												20					
Courses for PSU			24509 Special course for																													
Trainees	15		16	16																												
Courses for PSU				24510 PSU Slot					24511 PSU Slot							24512 PSU Slot																
Trainees				20	20				20	20						20	20															
Webinars	24224		24225		24226		24227	24308	24228		24229		24230		24231		24232				24233	24311	24234		24235		24236					
HAG/SAG Seminars								24309												24310		24312										
Trainees								25												25		25										
Misc.																																
Spare Capacity available	13	8	12	7	3	3	8	-2	3	3	18	13	13	13	3	3	3	68	68	8	13	-7	18	13	18	33	13	43	43	43	43	68

Calendar Of Courses SSTW 2024

Month & Year	Dec.2023				Jan.2024					Feb.2024				Mar.2024				Apr.2024					May 2024				June 2024			
Hostel Capacity	67	67	67	67	67	75	75	90	65	90	90	90	90	90	90	90	90	90	90	75	75	75	75	75	75	75	75	75	75	75
Date (Monday)	4	11	18	25	1	8	15	22	29	5	12	19	26	4	11	18	25	1	8	15	22	29	6	13	20	27	3	10	17	24
Institute holidays				25				26																						
Track courses	23624 Refresher Course		23626 Refresher Course (P.Way)			24601 Refresher Course (P.Way)			24603 Refr	24604 Refresher Course (P.Way)				24605 Refresher Course (P.Way)			24606 Refr	24607 Refresher Course (P.Way)					24609 Refresher Course (P.Way)			24610 Refr	24611 Refresher Course (P.Way)			
Trainees	25	25	25	25	25	25	25	25	25	25	25	25		25	25	25	25	25	25	25			25	25	25	25	25	25	25	
Track courses						24802							24807	24809								24815						24821		24823
Trainees						25							25	25								25						25		25
Bridge courses						24602 Refresher Course				24804								24812 Fabrication and inspection of								24819			24822	
Trainees						25	25	25		25								25	25	25						25			25	
Work courses	23625	23832	23830	23831	24801		24803				24805		24808		24810	24811 Special course for				24813	24608 Refresher Course		24816	24817	24818		24820			24824
Trainees	25	25	25	25	25		25				25		25		25	25	25			25	25	25	25	25	25		25			25
Courses for PSU	23907 Special Course for executives of DFCCIL GR. III Ph-II							24901 Special Course for executives of DFCCIL GR. I Ph-I													24902 Special Course for executives of DFCCIL GR. II Ph-I									
Trainees	17	17	17	17	17			40	40	40	40	40	40	40	40	40	40	40	40		25	25	25	25	25	25	25	25	25	25
Misc.												24806									24814									
Trainees												25									25									
Spare Capacity available	-17	-17	-17	-17	-17	-25	-25	-40	-15	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25

Month & Year	July 2024					Aug.2024				Sep.2024					Oct.2024				Nov.2024				Dec.2024					Jan.2025				Feb.2025			
Hostel Capacity	75	75	75	75	65	65	65	65	65	65	90	65	65	65	65	65	65	0	0	25	75	75	75	75	75	75	75	25	25	25	25	25	25	0	0
Date (Monday)	1	8	15	22	29	5	12	19	26	2	9	16	23	30	7	14	21	28	4	11	18	25	2	9	16	23	30	6	13	20	27	3	10	17	24
Institute holidays							15							2				31																	
Track courses	24612 Refresher Course (P.Way)			24614 Refr		24615 Refresher Course (P.Way)				24616 Refresher Course (P.Way)				24617 Refr	24618 Refresher Course (P.Way)			Diwali Holiday, No teaching activity		24619 Refresher Course (P.Way)			24620 Refr		24621 Refresher Course (P.Way)										
Trainees	25	25	25	25		25	25	25		25	25	25		25	25	25	25			25	25	25	25		25	25	25								
Track courses				24827																			24833	24834			24836								
Trainees				25																			25	25			25								
Bridge courses			24613 Refresher Course																		24831			24835											
Trainees			25	25	25																25			25											
Work courses	24825	24826 Special course for							24828		24829		24830									24832			24622 Refresher Course										
Trainees	25	25	25						25		25		25									25			25	25									
Courses for PSU					24903 Special Course for executives of DFCCIL GR. I Ph-II																24904 Special Course for executives of DFCCIL GR. II Ph-II														
Trainees	25	25			40	40	40	40	40	40	40	40	40	40	40	40	40				25	25	25	25	25	25	25	25	25	25	25	25	25		
Misc.																																			
Trainees																																			
Spare Capacity available	-25	-25	-25	-25	-15	-15	-15	-15	-15	-15	-40	-15	-15	-15	-15	-15	-15			25	-25	-25	-25	-25	-25	-25	-25	25	25	25	25	25	25		