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1	NAME OF THE DIRECTORATE		Bridge & Structure
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4	NAME OF THE RECORD/FILE/DOCUMENT/SPECIFICATION etc. AND ITS VOLUME/VERSION		Investigation for Dynamic Augment on Ballasted Deck concrete Bridges
5	TOTAL NO OF PAGES/IMAGES		57 (Approx.)
6	NAME,SIGNATURE AND DESIGNATION OF THE HANDING OVER RDSO OFFICIAL		R.K. Sharma SE/D/B&S CB-I
7	NAME,SIGNATURE AND DESIGNATION OF THE TAKING OVER CMC OFFICIAL		10/12/10
8	DATE OF HANDING OVER FILE/DOCUMENT etc.		
9	FIELDS FOR INDEXING		
	1	Type of Document (File/ DRAWING/TECHNICAL CIRCULAR/MODIFICATION SHEET/SPECIFICATION/NP)	Report
	2	Document No.	BS-24
	3	SUBJECT	concrete
	4	SUB-SUBJECT	Investigation for Dynamic Augment on Ballasted Deck concrete Bridges.
	5	VOLUME	one
	6	Sr. No.	From 1 To 57
	7	DATE OF CREATION OF FILE	12/1999
	8	Dealer	R.K. Sharma
10	DATE OF RECEIVING BACK THE DOCUMENT		
11	NAME, SIGNATURE AND DESIGNATIONOF THE RDSO OFFICAL RECEIVING BACK THE DOCUMENT AFTER SCANNING (No of papers to be checked by department)		Checked & Verified Total No. of Image = R.K. Sharma SE(D)
12	REMARKS/FEEDBACK IF ANY *(Quality of documents to be checked by department and certified)*		
13	CATEGORY OF DOCUMENTS A) COMPUTER GENERATED GOOD QUALITY B) COMPUTER GENERATED (DOT MATRIX) C) TYPE WRITTEN D) HAND WRITTEN		Mixed

Not final

GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS

REPORT

ON

INVESTIGATIONS FOR DYNAMIC AUGMENT ON BALLASTED DECK CONCRETE BRIDGES

REPORT NO. BS - 24

DECEMBER - 1999

RESEARCH DESIGNS AND STANDARDS ORGANISATION
LUCKNOW-226011

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INVESTIGATIONS FOR DYNAMIC AUGMENT ON BALLASTED DECK CONCRETE BRIDGES

1.0 Introduction

Dynamic Augmentation of stresses in bridges is a complex phenomenon, depending on various parameters of bridge and rolling stock design, as well as track geometry. This dynamic augment of stresses is usually taken into consideration, both in design of new bridges and checking strength of existing ones, by applying to the live load a multiplication factor termed as ' Impact Factor ' or ' Coefficient of Dynamic Augment' (CDA).

1.1 On Indian Railways the 'Impact factor' earlier laid down in clause 2.4 of the IRS Bridge Rules, was based on tests conducted in 1920s with steam locomotives at speed of 96 kmph and 72 kmph on BG and MG respectively. The formula for Impact factor arrived was :

$$I.F = \frac{20}{14+L} \text{ in metric units.}$$

Where L is the loaded length of span in meters.

This was derived by considering the variables causing dynamic effect with steam locomotives e.g. hammer blow, acceleration of reciprocating parts, vehicle oscillations, bridge vibrations, steam effect, lurching, track irregularities including rail joint etc.

1.2 With the introduction of diesel and electric locomotives, increase in maximum speed of passenger trains from 100 to 140 kmph and increase in axle loads of freight wagons from 16 to 22.9 tonnes on BG , based on the recommendations of 44th BSC meeting held in 1964, Railway board vide letter No. 62/W-6/TK/2 dated. 26.11.64 directed RDSO to carryout tests with the following objectives.

i) To ascertain as to whether the existing girder bridges of BG main line (BG ML) strength are safe for running diesel electric locomotives up to a speed of 120 kmph.

ii) To collect data, which could ultimately be used to revise impact formula for speed upto 160 kmph.

Subsequently vide letter No. 64/WSC/TK/18 dated 19.7.69, Railway Board directed RDSO to carryout basic studies for establishing the parameters for bridges on MG for introduction of high speed passenger traffic. Hence RDSO carried out a systematic study on steel bridges on B.G. & M.G..

Based on the values of CDA evaluated as a result of the tests conducted on different spans ranging from 3 m to 76.2 m with different train combinations and limited theoretical studies for long span girder bridges, the following formula was developed and incorporated in clause 2.4 of IRS Bridge Rule. (Annexure – I).

$$CDA = 0.15 + \frac{8}{6 + L}$$

where L is

i) Loaded length of span in meters for the position of the train giving the maximum stress in the member under consideration.
ii) 1.5 times the cross girder spacing in the case of stringers.
iii) 2.5 times the cross girder spacing in case of cross girders.

1.3 The dynamic response of Concrete bridges with ballasted deck will be different from those of unballasted steel span for the following reasons.

- Dead load/live load ratio is more
- Generally stiffer
- Damping of vibration is faster
- Concrete is heterogeneous in nature
- Support conditions in most of the concrete bridges are different.
- The resilience effect of ballasts , i.e. the depth of ballast cushion etc.

1.4 RDSO's report on, "Investigations for dynamic effects on girder bridges (BG & MG)", was presented as an informal item at 59th meeting of BSC held in July 1980 at Puri. In view of the importance of the subject, BSC constituted a sub committee to examine the report of RDSO and prepare draft amendment to the existing provisions in Bridge Rules for the further consideration of the BSC.

1.5 It was recommended by the subcommittee in their draft report that the present formula for calculating CDA with reduction factor due to ballast fill as per Clause 2.4.2.1 of IRS Bridge Rule may be continued for the ballasted deck bridges.

1.6 The sub committee had also observed that the British Code BS-5400 and ORE/UIC make no difference between ballasted and unballasted deck bridges as far as CDA values are concerned. Russian Railways, AREA and JNR provides for the reduction in the CDA values for ballasted deck bridges.

1.7 The 12th Extra ordinary meeting of BSSC committee held at Lucknow in Feb.1981, recommended that the present formula for calculating CDA for steel should be continued for concrete bridges having ballasted deck with a reduction factor as laid down in the Bridge Rule less than 25 m span length and without reduction factor for span 25 m and more than 25 m .

1.8 The Director Research/RDSO vide NP-9 of RB-1656 has approved a project " Dynamic Augment on Ballasted Deck Concrete Bridges" (RCC / PRC slab, PRC girders with deck slab, Composite steel girders with RCC deck slab) to determine CDA for these bridges and test may be done on some of these bridges to validate adoption of newly proposed formula as well as the existing reduction factor to be applied in such bridges.

2.0 Objective :

To determine the Coefficient of Dynamic Augment on Concrete ballasted deck bridges and validate the existing provision of CDA on the bridges or otherwise evolve new formula for incorporating in the Bridge Rules for Indian Railways.

3.0 Field trials on Indian Railways:

3.1 General: While planning the field trials it was kept in view that test should be conducted on different type of spans and different type of rolling stocks. Trials were accordingly carried out on both BG and MG on short, medium and long span ballasted deck concrete bridges with locomotives and other rolling stock earmarked for present and future high speed operations.

3.2 Bridge Tested: The trials were carried out on different types and spans of concrete bridges with existing ballast cushion. The details of bridges tested are shown in Table No.1. For the bridge no. 163, 162 (MG) and 54 (BG), the trials were repeated by raising the existing ballast cushion to see the effect of cushion. On perusal of the table, it is observed that the span length varies from 3.66 m to 40.0 m and bridge types are Concrete slab, girder, composite, box and continuous span bridges. The brief description of bridges tested is given below :

3.2.1. Bridge No. 162 (Report No. C-262 & BS-2)

Bridge No. 162 consisting of 5 spans of 12.2 m PRC girders located at Km. 187/11-12 between Bhawanipur Kalan and Balrampur stations on Gonda-Gorakhpur loop, MG Section of N.E.Rly. was found suitable for the test. The girders of the bridge were in good condition. Second span from Gonda end was selected as test span. The bridge is on a straight track permitting good view on either side of the bridge for the locomotive to run at a maximum speed of 100 kmph. The girders rested on steel to steel sliding bearings. The track on the bridge consisted of 60 R CWR, wooden Sleepers with M+7 sleeper density, depth of ballast cushion was about 200 mm on the bridge. Approaches were straight and level. The maximum permissible speed of the section was 75 kmph. The trials were repeated after increasing the ballasted cushion upto 300 mm.

3.2.2 Bridge No. 163 (Report No C-262 & BS-2)

Bridge No 163 (1 x 3.66 m) RCC slab and adjacent to Bridge No 162 was also selected for dynamic augment studies. The slab was in 2 parts longitudinally. The track structure and ballast cushion on this bridge as well as on approaches was the same as that on Bridge No. 162. The trials were repeated after increasing the ballasted cushion upto 300 mm.

3.2.3 Bridge No. 54 (Report No BS-1 & BS-3)

Bridge No.54 UP (3 x 18.3m + 2 x 12.2m) with PSC girders at km. 510/4-6 on Godhra-Ratlam section of W.Rly. is skew having a skew angle of 72 degrees. The track on the bridge consisted of 52 kg. SWR, 75lbs guard rails, wooden sleepers (M+7), canted bearing plates with four dog spikes and at some locations anticreep bearing plates with two-way keys. Ballast cushion was 300 mm. The track on the approaches consists of 52 kg SWR, steel sleepers, sleeper density (M+7) with loose jaws and keys. There are two curves i.e. curve no 17 of 2 degrees and curve no. 18 of 1 degree on NDLS approach at km 510/17 to 510/27 and 511/25 to 512/13 respectively. On BCT end approach there are two 1 degree curve no. 16 and 16 A at kms 509/3-4 to 508/13-14 and km 509/10-11 to 509/8-9 respectively. The maximum sectional speed of 100 kmph was permitted due to curves. The trials were repeated after increasing the ballast cushion upto 300 mm.

3.2.4 Bridge No. 356 (Report No C-263)

Morel Bridge No. 356 (16 x 18.3 m span) was selected for the trial. The bridge is situated at kms. 1069/11-15 between Nimoda and Narayanpur Tatwara Station of Kota - Gangapur City section of Western Railway. This new Morel bridge was constructed in June 1982 as the old bridge was damaged due to flood in 1981. It consists of 16 x 18.3 m span plate girder seated on twin RCC pillars founded on a group of 6 piles of 1.20 m diameter. The bridge has composite girders and carries double track on both UP and DN line. The floor system consists of ballasted RCC decks connected to the main girders by shear connectors. The girders at the support rest on elastomeric bearings. The track on the bridge consists of 3 panel 52kg welded rails, M+7 wooden sleepers, ballast cushion 300 m m. This new bridge was opened to traffic on 25.6.82. The maximum sectional speed permitted was 110 kmph.

3.2.5 Bridge No 1086/1 (Report No BS-8)

The Betwa bridge (span 18 x 23.0m) span, a composite bridge is situated between Matatila - Basai section of C.Railway. Span No. 18 from Bombay end was selected for test. The track on the bridge consisted 52 kg rail, wooden sleeper with M+6 sleeper density and ballast cushion was 300 m m. Approaches of the bridge consisted 60 kg rail (LWR), PRC sleepers with M+8 sleeper density and 300 mm ballast cushion.

3.2.6 Bridge No. 2/25576 (Report No BS-7)

The bridge is located between Roha -Veer section of Konkan Railway. It is a PSC Box girder resting on Neoprene bearing and 4 m long approach slab has been provided over boulder and Morrum cushion at both ends of the bridge by extending deck slab. The bridge consists (3 x 10.0m + 2 x 26.226 m) spans and is a road under bridge constructed in the year 1992. The track on bridge and approaches consisted 52 kg, LWR, 75lbs guard rail, PSC sleeper, (M+7) sleeper density with the help of elastic steel clip and 250 mm ballast cushion.

3.2.7 Bridge No. 627 (Report No BS- 20)

The bridge is located between Ratnagiri and Nivasar section of Konkan Railway. It is a continuous PSC box girder having spans 2 x 30 m + 9 x 40 m on the panvel nadi at km 211.03. The trial was conducted on both the spans of 30 and 40 m. In addition to WDM2 locos, the trial was conducted with WDG2 type of locomotives. Track structure on bridge and its approaches consists 52 kg LWR rail, concrete sleepers with M+7 sleeper density ,52 Kg guard rails and 190 mm special SEJ on approaches were provided. Ballast cushion was 250 mm.

3.3 Rolling stock utilized: The following type of locomotives and other rolling stock were utilised in trials:

		BG	MG
a)	Diesel electric locomotives	WDM2,WDM2A WDG2,WDS6	YDM4
b)	Electric locomotive	WAM4, WAG5A	--
c)	Steam locomotives	--	YP, YG
d)	Wagons	Loaded BOXC Wagons.	--

3.4 Test Trains: It consists Single, Coupled locomotives and Single locomotive + loaded BOXC wagons. Details of axle load, axle spacing for the rolling stock used for the trials are given in figure 1/1 and 1/2.

3.5 Test speeds and test runs:

3.5.1 Trials were carried out at the following speeds for diesel electric locos:

BG - Quasi Static, 30,50,70,80,90,100,110, 120 and 130 kmph
MG – Quasi Static, 30.50.70.80,90 & 100 kmph.

In case of steam locomotives trials were carried out up to 90 kmph and for Electric /Diesel locomotive the speed was restricted upto 100 kmph on MG. On BG, the speed for Electric /Diesel locomotives the speed was upto 120/130 kmph. Where BOXC wagons were attached, the max. tests speed had to be restricted to 70 kmph.

3.5.2 At each speed, six runs had generally been carried for all speed groups except in a few cases, where due to limitation of block and availability of loco, lesser number of runs were taken. The various runs of a speed group have been carried out at speeds as nearly identical as possible the deviation in the speed permitted being ± 5 kmph. Thus in the speed group of say 100 kmph, the actual speed could range from 95 to 105 kmph. The accuracy of the speed was checked from the timer provided with the oscillograph recording equipment.

3.5.3 The UIC/ORE in course of their study in Question –D 23 had considered a speed upto 15 kmph as Quasi Static and considered runs upto this speed as datum for evaluating CDA. Thus during the test on each day two such runs at speed upto 15 kmph were recorded at the beginning of the speed runs and two runs at end of the days work.

3.5.4 Parameters measured: The following measurements were taken during the trials:

a) Bending Strains
b) Shear Strains .
c) Vertical deflection at mid span of girders.

4.0 Instrumentation:

4.1 Electric resistance strain gauges were used to measure bending strains, shear strains and speed of the train. Gauges were fixed at locations, where maximum stresses are expected. LVDT (Linear Variable Differential Transformer) was used for measuring deflection at the mid span of the girder. The locations of strain gauges fixed for measuring bending strain, shear strain , measurement of the speed of the test train and LVDT for deflection for different types of bridges are given below:

4.1.1 Bending Strain :

i) In Concrete deck slab , and composite bridge, electric resistance strain gauge were fixed on top and bottom of the deck slab at the mid span.
ii) In Concrete girders at top and bottom flange of the girder at the mid of the span electric strain gauges were fixed,
iii) In Box girder the strain gauges were fixed on the deck inside the box and bottom of the deck at the mid span.

4.1.2 Shear Strain :

Shear strains are measured at neutral axis of the girder near the support at a distance of 1.5 times the depth of girder, from the centre of bearings for PSC girder and Box girder bridges.

4.1.3 Deflection:

Deflection was measured for all types of bridges at the centre of the mid span of the slab/girders

4.2 Output of the various gauges were fed through shield cables as input to the amplifiers and then to recording equipment. The output from the recording equipment was obtained in the analog form on the strip chart recording paper. Recording of the data was done by analogue recording instruments.

4.3 Location of strain gauges and LVDT fixed for recording different parameters in different types of bridge are given in fig. 2/1 to 2/4. Specifications of the strain gauges, LVDT and recording equipments used for the test are given in Annexure II.

5.0 Method of test:

All channels were checked, balanced and calibrated every day before the beginning of the test. Details of calibration factor is given in Annexure III. On test train approaching the instrumented span, a signal was given and recorders were switched on. Recording continued till the last vehicle passed. Speed of test train was controlled from the speedometer of locomotive and was confirmed from the timer by signal from wheel marker fixed on the neutral axis of the one of the rail. Crawling and speed runs were recorded from both sides of the bridge. Calibration of all the channels were checked at the end of test also.

6.0 Analysis of data :

6.1 Test records:

The records consist of Oscillograms taken during different runs. Few typical oscillograms under single and coupled WDM2 locomotives at crawling and high speed are shown in Fig. 3/1 & 3/2.

6.2 Amplitude of highest peak of each channel for every run was measured. Co-efficient of Dynamic Augment (CDA) has been worked out as per the following formula:

$$CDA = \frac{Av - Aoav}{Aoav} = \frac{Av}{Aoav}$$

Where,

Av	=	Amplitude of peak at test speed at some location
Ao	=	Amplitude of peak at crawling speed for same location.
Aoav	=	Average of Ao values for all the crawling runs of a block period.

6.3 Aoav is calculated for each block period. In case any individual value of Ao is varying by more than ± 15% of Aoav then that value is ignored and Aoav is recomputed. Process is continued till all individual readings are within ± 15% of Aoav. This has been done to eliminate freak value of Ao, as that would influence the values of CDA.

6.4 Although the tests were conducted with steam locomotives but as the steam locomotives has already been phased out from the Indian Railways the CDA results due to these locomotives have not been considered for arriving at the final conclusions.

6.5 The CDA observed from deflection (Table 2 & 3) has not been considered to arrive at final conclusion as the design of the girder is primarily based on the concept of permissible stresses in different components.

6.6 The max. value of CDA in % , analysed by the oscillogram for different speeds and different train compositions of the bridge tested are given in Table 2.

6.7 The observed max. value of CDA in bending, shear and deflection for different train compositions extracted from Table 2 are given in Table 3.

6.8 The observed max. value of CDA for all Diesel/Electric train compositions extracted from Table 3 are given in Table 4.

6.9 The absolute observed max. value of CDA extracted from Table 4 and % variation from IRS values are shown in Table 5.

7.0 Effect of ballast cushion on CDA:

7.1 A reduction factor in CDA has been provided upto the depth of fill 900 mm in clause 2.4.2.1(a) of Bridge Rule . To observe the effect of ballast cushion on CDA, the trials on bridge no: 162,163 on MG and 54 on BG were conducted by raising the existing ballast cushion from 200 mm to 300 mm. The results of CDA for 200 mm & 300 mm ballast cushion are shown in table 3.

7.2 On perusal of table 3 it is seen that no definite trend is observed in CDA values after increasing the ballast cushion from 200 mm to 300 mm. For 3.66 m span, the values are reduced considerably for 300 mm ballast cushion as compared with 200 mm ballast cushion. Max. observed value was 50 % as against 77.99% as per IRS Bridge Rule. For 12.2 m and 18.3 m span for 300 mm ballast cushion the values of CDA observed were even higher than those observed for 200 mm ballast cushion. In one case the observed value was 6% higher than computed from IRS Bridge Rule. The CDA values are dependent on various parameters such as irregularities of track profile, type of ballast, packing conditions, maintenance of bridge approaches, acceleration of rolling stock while entering the bridge etc. These parameters could not be monitored due to logistical problems.

7.3 It may be seen from para 1.6 of this report that except Soviet Railways, AREA and Japanese National Railways which have provided a reduction factor for the depth of ballast cushion on concrete bridges, no other Railway have considered the effect of ballast cushion for computing the CDA. On Soviet Railways the effect of ballast cushion has not been considered upto 25 cm depth of ballast. The Co-efficient of dynamic augment uniformly decreases to 0.5 from 25 cm to 100 cm depth of ballast cushion. No further reduction is made for ballast cushion more than 100 cm. AREA has used 90 % of the value of CDA taken for non ballasted deck bridges. Japanese National Railways consider the effect of ballast cushion for spans less than 100 m.

8.0 Observations and discussions:

8.1 The characteristics of dynamic response of bridges are found to vary for different span ranges. For this purpose, the bridges are divided into three categories viz.

1) Short span bridges upto 6.5 m
2) Medium span bridges from 6.5 m to < 30 m
3) Long span bridges of 30 m and above.

Comparison of observed max. value of CDA with IRS values are given in table 5.

8.2 Short Span (3.66 m)

Test was conducted on one span of 3.66 m on MG bridge. The max. value of CDA observed under single diesel electric locomotive was about 0.23 % lower than as per IRS Bridge Rule (Table- 5).

8.3 Medium Span (6.5 m to < 30 m)

Tests were conducted on 12.2 m, 18.3 m and 23.0 m spans on both MG and BG bridges. In one case the max. value of CDA observed on 12.2 m span MG bridge was about 5% higher than those computed by the existing IRS formula. In all other cases the absolute maximum value of CDA observed was 7.5 % lower than that computed from IRS Bridge Rule.

The higher value observed on MG bridge has not been considered due to adoption of unigauge policy on Indian Railways in future.(Table 5)

8.4 Long Span (30.0 m & above)

The tests were conducted on two spans of 30 m & 40 m on BG. The absolute max. values of CDA observed for 30 m & 40 m spans were 0.59 % and 7.38% respectively lower than those computed with IRS Bridge Rule (Table 5).

8.5 It is observed that the values of CDA for different rolling stock used for the trials generally increases upto 100 kmph and there after it remains almost constant for all span length of the bridges upto maximum test speed (Fig 4/1 to 4/32).

8.6 Max. CDA values observed in bending are generally higher than those observed in shear and deflection. (Table 2).

8.7 Max. CDA values observed are lower than those with the IRS values for different span tested for all diesel/electric test trains composition (Fig. 5/1 to Fig. 5/4).

9.0 Conclusions:

In all the test conducted on BG bridges with different train compositions and speed groups, the observed values of CDA in all the cases were found less than the values computed as per Bridge Rule. It can be seen from fig. 5/4 that though all the observed values of CDA are within the curve as per the Bridge Rule but some values are in very close proximity of the curve. Therefore, existing provision of CDA is valid and does not need any modification. In absence of the field tests on pipe culverts and arch bridges, it is proposed to continue the existing provision of Bridge Rule of computing CDA for these type of bridges.

Table No.1

DETAILS OF BRIDGES TESTED WITH DIFFERENT SPAN SIZE

SN	Span in m	No. of span	Ballast cushion in mm	Br. No.	Type of Bridge	Section & Rly.	RDSO's Report No.	Date of test
1.	3.66	1	200	163	PRC-slab	Gonda – Balarampur MG, NER	C-262	Feb-March-87
2.	"	"	300	"	"	"	BS-2	Apr-92
3.	12.2	5	200	162	PRC girder	"	C-262	June-87
4.	"	"	300	"	"	"	BS-2	Apr-92
5	18.3	3	200	54UP	PRC girder	Godhra-Ratlam BG WR	BS-1	June-89
6.	12.2	6	200	"	"	"	BS-1	Dec-92
7.	18.3	3	300	"	"	"	BS-3	Dec-92
8.	12.2	6	300	"	"	"	BS-3	Dec-92
9.	18.3	16	300	356 (Morel bridge)	Composite girder	Kota-Gangapur city BG ,WR	C-263	May-90
10	23.0	18	300	1086/1 (Betwa bridge)	Composite girder	Matatela-Basai ,CR	BS-8	Sept-94
11	23.0	2	250	2/25576	PSC- Box	Roha-Veer BG,Konkan Rly.	BS-7	Dec-94
12	30.0	2	250	627(Panvel via duct)	PSC-Box	Ratnagiri-Nivasar BG, KRCL	BS-20	May - 99
13	40.0	9	250	"	"	"	"	May -99

Table No. 2

Observed maximum CDA (%) for different spans under various train composition and speeds (BG & MG)

SN	Span length in mm	Bridge No.	Section and Rly.	Depth of ballast cushion in mm	Train composition	Parameters measured	Observed value of CDA %									Remarks
							Speed group in kmph									
							30	50	70	80	90	100	110	120	130	
1	3.66	163	GKP-GD loop (MG) NER	200	Single YDM4	Bending stresses	67	67	77	62	77	83				
						Deflection	56	56	56	40	56	88				
					Single YP	Bending Stresses	-	80	83	100	-					
						Deflection	-	66	66	83	-					
1a	"	"	"	300	Single YDM4	Bending Stresses	33	33	33	33	33					
						Deflection	45	45	45	45	9					
					Single YP	Bending Stresses	50	17	50	50						
						Deflection	50	50	100	0						
2	12.2	162	"	200	Single YP	Bending Stresses	14	33	33	44						
						Shear Stresses	19	28	52	60						
						Deflection	30	19	28	42						
					Coupled YP	Bending Stresses	22	22	29	41						
						Shear Stress	16	33	63	60						
						Deflection	9	24	38	45						
					Single YG	Bending Stresses	22	22	22							
						Shear Stresses	17	30	32							
						Deflection	20	28	28							
					Single YDM4	Bending Stresses	15	20	31	40	40	33				
						Shear Stresses	13	13	14	26	44	40				
						Deflection	0	0	17	25	25	25				
					Coupled YDM4	Bending Stresses	20	31	31	36	32	39				
						Shear Stresses	14	12	35	34	35	29				
						Deflection	17	13	13	25	24	19				

Table No. 2

Observed maximum CDA (%) for different spans under various train composition and speeds (BG & MG)

SN	Span length in mm	Bridge No.	Section and Rly.	Depth of ballast cushion in mm	Train composition	Parameters measured	Observed value of CDA % Speed groups in kmph 30	50	70	80	90	100	110	120	130	Remarks
2a	12.2	162	GKP-GD Loop (MG) NER	300	Single YP	Bending Stresses	25	50	50	50						
						Shear Stresses	5	7	33	20						
						Deflection	3	13	13	19						
					Coupled YP	Bending Stresses	29	33	50	50						
						Shear Stresses	14	43	14	43						
						Deflection	16	24	33	45						
					Single YDM4	Bending Stresses	33	36	48	50	50					
						Shear Stresses	11	-	-	11	25					
						Deflection	0	7	7	17	36					
					Coupled YDM4	Bending Stresses	20	20	27	20	20	27				
						Shear Stress	14	0	14	0	29	14				
						Deflection	-	-	11	20	27	35				
3	12.2	54UP	Godhara-Ratlam (BG).WR	200	Single WDM2	Bending Stresses	9	9	19		33	39	35	35		
						Shear Stresses	12	12			12	30	30	30		
						Deflection	17	17	17		22	37	37	39		
					Coupled WDM2	Bending Stresses	-	12	32		27	27	29	32		
						Shear stresses	-	7	13		20	27	27	20		
						Deflection	-	7	21	-	29	29	36	36		
					Single WAG5A + 6 loaded BOXC wagon	Bending Stresses	16	27	33	-	-		-	-		
						Shear Stresses	21	21	36	-	-		-	-		
						Deflection	11	19	36	-	-		-	-		

Table No. 2

Observed maximum CDA (%) for different spans under various train composition and speeds (BG & MG)

SN	Span length in mm	Bridge No.	Section and Rly.	Depth of ballast cushion in mm	Train composition	Parameters measured	Observed value of CDA % Speed groups in kmph									Remarks
							30	50	70	80	90	100	110	120	130	
3	18.3	54 UP	Godhara - Ratlam (BG)WR	200	Single WDM2	Bending Stresses	12	14	16	-	28	25	18	21		
						Shear Stresses	4	4	11	-	14	14	11	14		
						Deflection	4	4	8	-	12	12	12	12		
					Coupled WDM2	Bending Stresses	-	15	15	-	24	24	24	32		
						Shear Stresses	-	8	14	-	0	13	13	17		
						Deflection	-	8	12	-	12	15	19	15		
					Single WAG5A + 6 loaded BOXC wagons	Bending Stresses	12	12	19	-	-	-	-	-		
						Shear Stresses	23	23	23	-	-	-	-	-		
						Deflection	4	0	8	-	-	-	-	-		
3a	"	"	"	300	Single WDM2A	Bending Stresses	25	25	30		30	30	25	25		
						Shear Stresses	13	13	25		0	25	0	0		
						Deflection	5	12	17		17	5	8	8		
					Coupled WDM2A	Bending Stresses	19	33	20		32	20	20	33		
						Shear Stresses	11	11	25		25	25	11	25		
						Deflection	4	4	8		13	4	4	4		
					Single WAG5A+ 6 loaded BOXC wagons	Bending Stresses	25	22	26		-	-	-	-		
						Shear Stresses	1	8	30		-	-	-	-		
						Deflection	8	8	17		-	-	-	-		

Table No. 2

Observed maximum CDA (%) for different spans under various train composition and speeds (BG & MG)

SN	Span length in mm	Bridge No.	Section and Rly.	Depth of ballast cushion in mm	Train composition	Parameters measured	Observed value of CDA % Speed groups in kmph 30	50	70	80	90	100	110	120	130	Remarks
3a	12.2	"	"	"	Single WDM2A	Bending Stresses	25	25	38		25	42	33	38		
						Shear Stresses	21	36	22		36	36	-	-		
						Deflection	12	20	40		60	55	55	47		
					Coupled WDM2A	Bending Stresses	43	38	33		38	38	38	38		
						Shear Stresses	14	14	14		29	29	43	29		
						Deflection	0	9	18		36	42	42	33		
					Single WGA5A+ 6 loaded BOXC wagon	Bending Stresses	25	25	38		-	-	-	-		
						Shear Stresses	29	14	29		-	-	-	-		
						Deflection	8	15	23		-	-	-	-		
4	18.3	356(composite)	Kota-GGC (BG),WR	300	Single WDM2A	Bending Stresses	6	8	17	-	17	19	19	22		Only deck slab
					Coupled WDM2A	Bending Stresses	-	7	13	-	20	13	17	20		"
5	23.00	1086/1(composite)	Matatila-Basai (BG),C.R.	300	Single WDM2	Bending Stresses		-	31	-	0	31				"
					Coupled WDM2	Bending Stresses	-	7	-	32	7	-	5	32		"
6	23.00	2/25576 (Box)	Roha - Veer (BG),KRCL	250	Single WDM2	Bendig Stresses	7	15	15	-	32	25	32	29	29	
						Shear Stresses	9	3	9	-	9	9	9	18	18	
						Deflection	0	3	5	-	0	0	0	3	5	
					Coupled WDM2	Bending Stresses	8	16	21	-	27	10	27	22	27	
						Shear Stresses	3	3	7	-	3	7	7	3	7	
						Deflection	3	3	7	-	7	5	3	5	5	
					Single WDM2+ 5 loaded BOXC wagons	Bending Stresses	5	17	16	-	29	-	-	-	-	
						Shear Stresses	7	17	17	-	17	-	-	-	-	
						Deflection	3	3	3	-	-	-	-	-	-	

Table No. 2

Observed maximum CDA (%) for different spans under various train composition and speeds (BG & MG)

SN	Span length in mm	Bridge No.	Section and Rly.	Depth of ballast cushion in mm	Train composition	Parameters measured	Observed value of CDA % Speed groups in kmph 30	50	70	80	90	100	110	120	130	Remarks
7	30	627	RN-Nivasar (BG),KRCL	250	Single WDM2	Bending Stresses	20	37	33	-	33	33	27	27	-	
						Shear Stresses	18	25	25	-	25	4	12	12	-	
						Deflection	9	9	9	-	9	4	9	8	-	
					Coupled WDM2	Bending Stresses	-	-	-	-	-	17	-	-		
						Shear Stresses	-	-	-	-	-	13	-	-	-	
						Deflection	-	-	-	-	-	4	-	-	-	
															-	
					Single WDM2 + 6 loaded BOXC wagon	Bending Stresses	-	29	-	-	-		-	-	-	
						Shear Stresses	-	7	-	-	-		-	-	-	
						Deflection	-	-	-	-	-		-	-	-	
					Single WDM2 + 3 BT wagons + 1BV	Bending Stresses	13	28	-	-	-		-	-	-	
						Shear Stresses	11	11	-	-	-		-	-	-	
						Deflection	3	9	-	-	-		-	-	-	
					Single WDG2	Bending Stresses	7	18	18	-	29	18				
						Shear Stresses	-	-	-	-	-	4				
						Deflection	1	1	1	-	1	1				
					Single WDM2+ Single WDG2	Bending Stresses	9	23	23	-	23	23	29	-	-	
						Shear Stresses	-	8	22	-	8	8	22	-	-	
						Deflection	7	7	9	-	9	4	7	-	-	
					Single WDG2+ 6 loadedBOXC	Bending Stresses	-	-	-							
						Shear Stresses	24	24	10	-	-		-	-	-	
						Deflection	2	5	2							

Table No. 2

Observed maximum CDA (%) for different spans under various train composition and speeds (BG & MG)

SN	Span length in mm	Bridge No.	Section and Rly.	Depth of ballast cushion in mm	Train composition	Parameters measured	Observed value of CDA % Speed groups in kmph									Remarks
							30	50	70	80	90	100	110	120	130	
8	40	627	RN-Nivasar (BG),KRCL	250	Single WDM2	Bending Stresses	27	22	22	-	12	9	22	12	-	
						Shear Stresses	25	11	19	-	7	19	26	19	-	
					Coupled WDM2	Bending Stresses	-	-	-	-	-	27	18	-	-	
						Shear Stresses	-	-	-	-	-	-	-	-	-	
							-					-				
					Single WDM2 + 6 loaded BOXC wagon	Bending Stresses	-	5	-	-	-		-	-	-	
						Shear Stresses	-	5	-	-	-		-	-	-	
					Single WDM2 + 3 BT wagons + 1BV	Bending Stresses	11	11	-	-	-		-	-	-	
						Shear Stresses	3	3	-	-	-		-	-	-	
					Single WDG2	Bending Stresses	14	14	14	-	30	14	-	-	-	
						Shear Stresses	0	6	6	-	13	6	-	-	-	
					Single WDM2+ Single WDG2	Bending Stresses	17	17	13	-	17	13	17	-	-	
						Shear Stresses	3	8	3	-	8	3	8	-	-	
					Single WDG2 + 6 loaded BOXC wagon	Bending Stresses	21	5	20	-	-		-	-	-	
						Shear Stresses	13	18	13	-	-		-	-	-	

Table No.3

Absolute Max. observed value of CDA in % for different span and Train Composition for bending, shear and deflection.

S N	Span in m	Type of rolling stock	Depth of ballast cushion (In mm)	Absolute max. observed value of CDA in % for the parameters			CDA as per IRS formula
				Bending Stresses	Shear Stresses	Deflection	
1	3.66 (slab) (MG)	Single YDM4	200 300	83 33	- -	88 45	83.19 77.99
		Single YP	200 300	100 50	-	83 100	
2	12.2 (Girder) (MG)	Single YP	200 300	44 50	60 33	42 19	50.56 47.40
		Coupled YP	200 300	41 50	63 43	45 45	
		Single YG	200	22	32	28	
		Single YDM4	200 300	40 50	44 25	25 36	
		Coupled YDM4	200 300	39 27	35 29	25 35	
3.	12.2 (Girder) (BG)	Single WDM2A	200 300	39 42	30 36	39 60	50.56 47.40
		Coupled WDM2A	200 300	32 43	27 43	36 42	
		Single WAG5A + 6 loaded Box wagon	200 300	33 38	36 29	36 23	
4.	18.3 (Girder) (BG)	Single WDM2A	200 300	25 30	14 25	12 17	41.33 38.75
		Coupled WDM2A	200 300	32 33	17 25	19 13	
		Single WAG5A + 6 loaded Box wagons	200 300	19 26	23 30	8 17	
5.	18.3 (Composite) (BG)	Single WDM2A	300	22 *	-	-	38.75
		Coupled WDM2A	300	20*	-	-	
6.	23.0 (Composite) (BG)	Single WDM2A	300	31*	-	-	34.58
		Coupled WDM2A	300	32*	-	-	

Table 3 (contd.)

S N	Span in m	Type of rolling stock	Depth of ballast cushion(In mm)	Absolute max. observed value of CDA in %			CDA as per IRS formula
				Bending Stresses	Shear Stresses	Deflection	
7.	23.0 (Box) (BG)	Single WDM2	250	32	18	5	35.56
		Coupled WDM2	250	27	7	7	
		Single WDM2 + 5 loaded Box wagons	250	29	17	3	
8.	30.0 (Box) (MG)	Single WDM2	250	37	25	9	37.22
		Coupled WDM2		18	13	4	
		Single WDM2 + 6 loaded box wagon		29	7	-	
		Single WDG2		29	4	1	
		Single WDM2 + Single WDG2		29	22	9	
		Single WDG2 + 6 loaded box wagon		-	24	5	
		Single WDM2 + 3BT wagon + 1BV		28	11	9	
9	40.0 (Box) (MG)	Single WDM2	250	22	26	-	32.39
		Coupled WDM2		27	-	-	
		Single WDM2 + 6 loaded box wagon		5	5	-	
		Single WDG2		30	13	-	
		Single WDM2 + Single WDG2		17	8	-	
		Single WDG2 + 6 loaded box wagon		21	18	-	
		Single WDM2 + 3BT wagon + 1BV		11	3	-	

Note: * values are for deck slab only.

Table No.4

Comparison of Max. CDA (%) with IRS values for different train compositions with different span

S.N.	Span in m	Effective span in m	Ballast cushion in mm	IRS Values.	Maximum CDA observed for different train composition.								Remarks
					Single Diesel/Electric locomotive		Coupled Diesel/Electric locomotive		Single Diesel/Electric + 6 loaded BOXC		All Diesel/Electric train composition		
					Bending	Shear	Bending	Shear	Bending	Shear	Bending	Shear	
1	3.66	4.18	300	77.99	33	-	-	-	-	-	33	-	
2	12.20	13.10	300	47.40	50	36	38	43	32	29	50	43	
3	18.30	19.40	300	38.75	30	25	33	25	23	30	33	30	
4	23.00	24.20	300	34.58	31	-	32	-	-	-	32	-	
5	23.00	24.43	250	35.56	32	18	27	7	29	17	32	18	
6	30.00	30.00	250	37.22	37	25	29	23	29	24	37	25	
7	40.00	40.00	250	32.39	30	18	27	8	21	18	30	18	

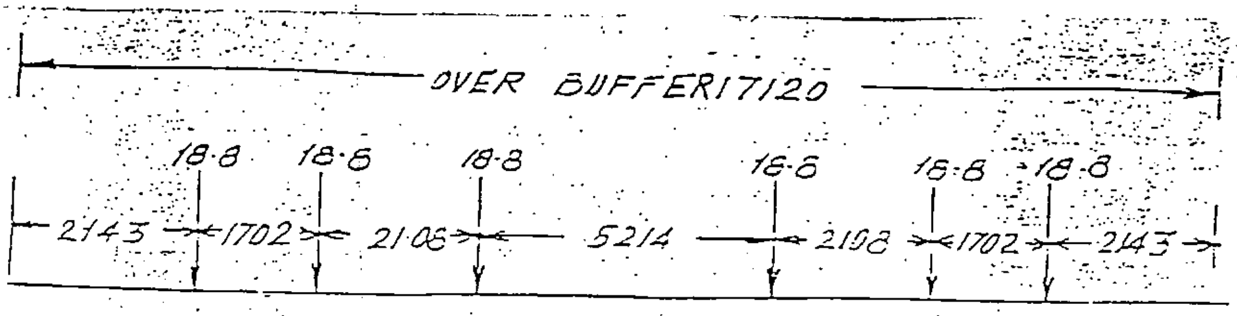
Table No. 5

Absolute Max. CDA Values obtained for different bridges for Diesel/ Electric Locomotives with their IRS values.

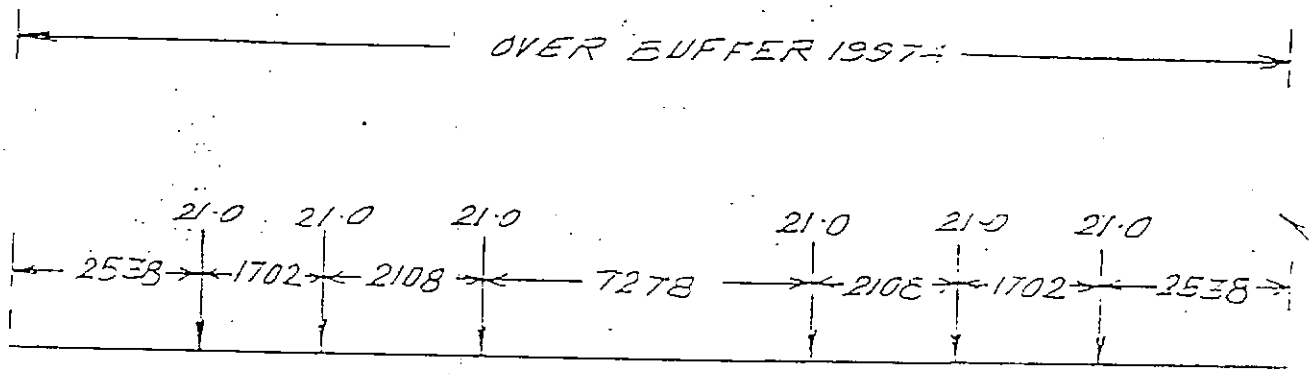
S. No	Br. No.	Span in m	Effective span in m	Depth of Ballast cushion in mm	Absolute Max. value of CDA observed in %	IRS values	% variation in Max. Observed values w.r.t. IRS values.
1	163	3.66	4.18	200	83	83.19	+0.23
2	162	12.2	13.10	300	50	47.40	-5.49
2(a)	54	12.2	13.10	300	43	47.40	+9.28
3	54	18.3	19.40	200 300	32 33	41.33 38.75	+22.57 +14.84
3(a)	356	18.3	19.40	300	22	38.75	+ 43.23
4	1086/1	23.0	24.20	300	32	34.58	+7.46
5	2/25576	23.0	24.43	250	32	35.56	+10.01
6	627	30.0	30.00	250	37	37.22	+0.59
7	627	40.0	40.00	250	30	32.39	+7.38

Note : (-) sign indicate high % variation (+) sign indicate low % variation.

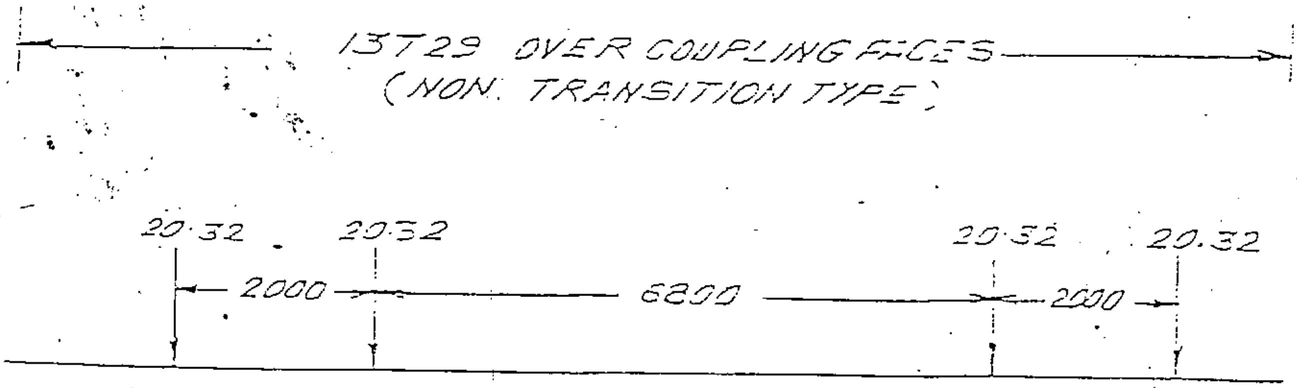
Axle load and axle spacing of various rolling stock used in the trials.



DIESEL ELECTRIC LOCOMOTIVE
CLASS - WDM_2A



ELECTRIC LOCOMOTIVE
CLASS - WAG5A



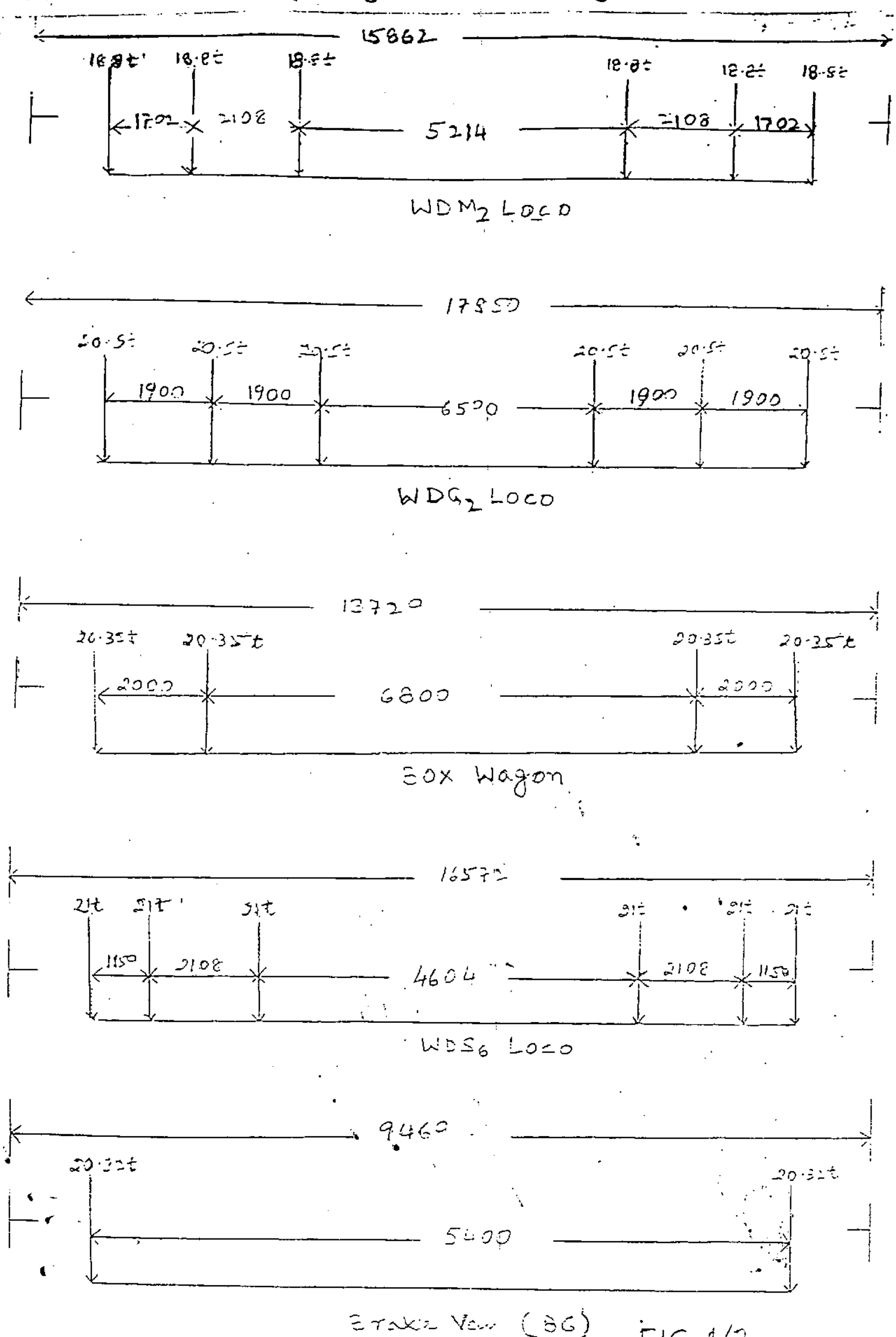
STANDARD OPEN BOGIE WAGON
TYPE - 'BOX C'

NOTE:-
ALL DIMENSIONS IN mm AND AXLE LOAD IN TONNES.

FIG. 1/1

DYNAMIC EFFECT ON PSC GIRDER BRIDGE No. 54 UP (2X12·2m + 3X18·3 m SPAN) AXLE LOAD & SPACING OF WHEELS OF LOCOMOTIVE & ROLLING STOCK.

Axle load and axle spacing of various rolling stock used in the trials.



NOTE– ALL DIMENSIONS ARE IN MM AND AXLE LOAD IN TONNES

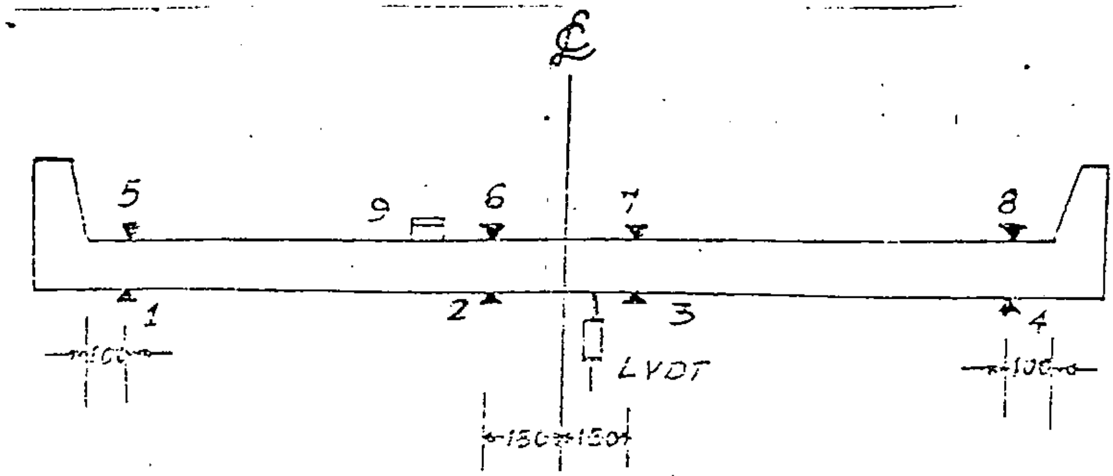
FIG. 1/2

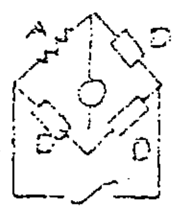
Axle Load & Axle Spacing.

Dynamic Effect on PSC gir

Bridge No. 627 on

Location of Instrumentation of different type of bridge tested.





CIRCUIT DIAGRAM

DETAILS OF CHANNELS.

BENDING	TENSILE	= 4
	COMPRESSIVE	= 4
VERT. ACC. OF DECK		= 1
" DEFLECTION		= 1
WHEEL MARKER		= 1
	TOTAL	= 11

LEGEND

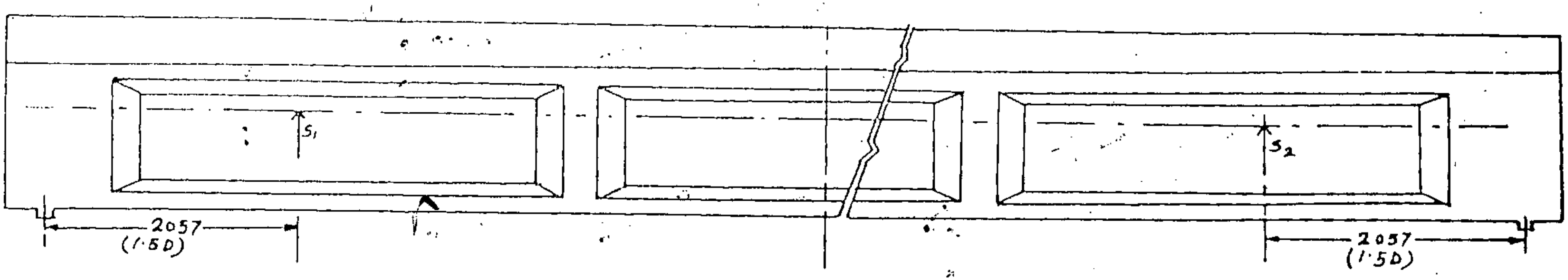
STRAIN GAUGE	△
ACCELEROMETER	(symbol)
LVDT	(symbol)

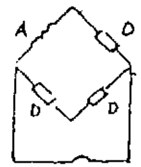
FIG - 2/1

ALL DIMENSIONS ARE IN mm.

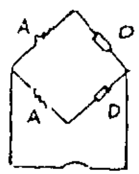
DYNAMIC EFFECT ON
CONCRETE BRIDGE NO 163
(1X3.6 m SPAN)
DETAILS OF INSTRUMENTATION

Location of Instrumentation of different type of bridge tested.





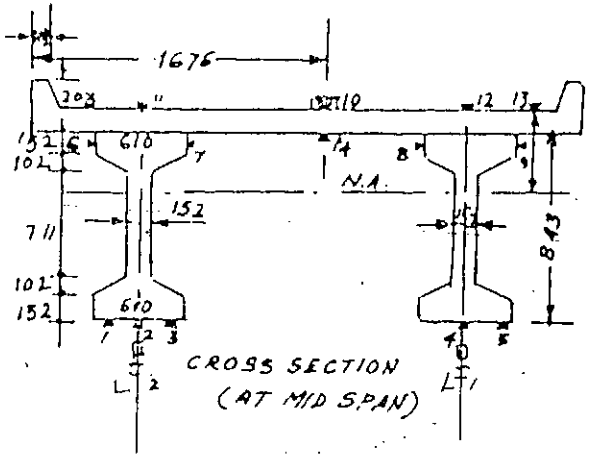
CIRCUIT DIAGRAM FOR BENDING STRAIN (GAUGES 1 TO 14)



CIRCUIT DIAGRAM (FOR SHEAR GAUGES)

A = ACTIVE GAUGE

D = DUMMY "



CROSS SECTION (AT MID SPAN)

DETAILS OF CHANNELS

STRAIN GAUGES	
BOTTOM FLANGE (GIRDER)	5
TOP " "	4
TOP OF DECK SLAB	4
BOTTOM " "	1
WHEEL MARKER	1
SHEAR GAUGES	4
VERTICAL DEFLECTION	2
VERT. ACC. CENTRE OF SLAB	1
TOTAL CHANNEL ON GROUND	22
CHANNELS IN THE LOCOMOTIVE	2
TOTAL	24

LEGEND

STRAIN GAUGE ▲

SHEAR " ↑

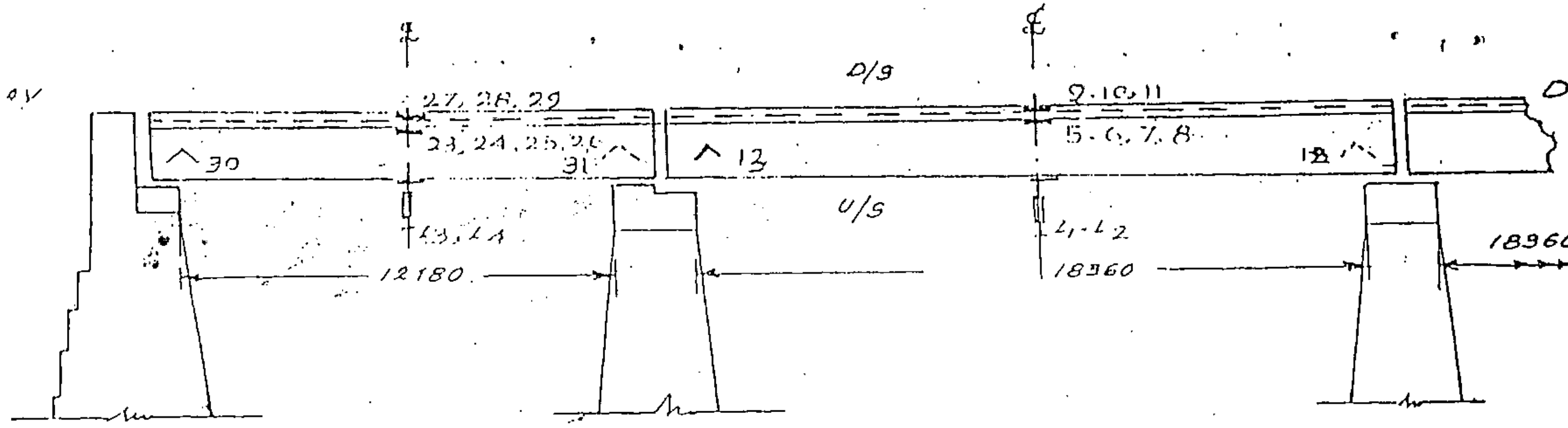
ACCELEROMETER ⊓

1. ALL DIMENSIONS ARE IN MILLIMETRES.
2. DRAWING NOT TO SCALE.

FIG - 2/2

DYNAMIC TESTS ON CONCRETE BRIDGE No. 162 (5X12·2m SPAN)

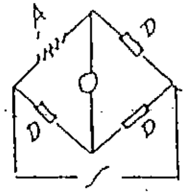
DETAILS OF INSTRUMENTATION



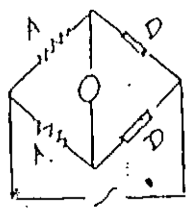
ELEVATION

DETAIL OF GAUGES.

LOCATION	GAUGES 18.3m	12.2m	CHANNEL
TOP FLANGE	4	4	8
BOTTOM "	4	4	8
TOP DECK	3	3	6
SHEAR	4	4	4
WHEEL MARKER	1	-	1
LVDT	2	2	4
TOTAL	18	17	31

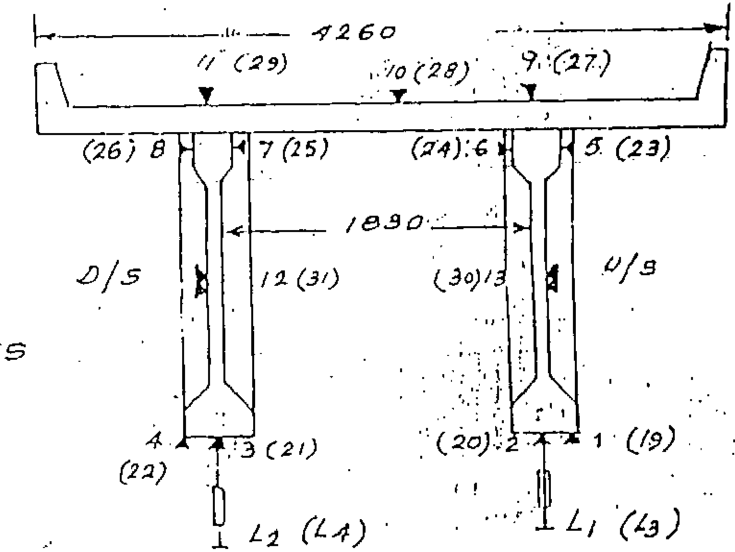


CIRCUIT FOR BENDING GAUGES



CIRCUIT FOR SHEAR GAUGES

NOT TO SCALE



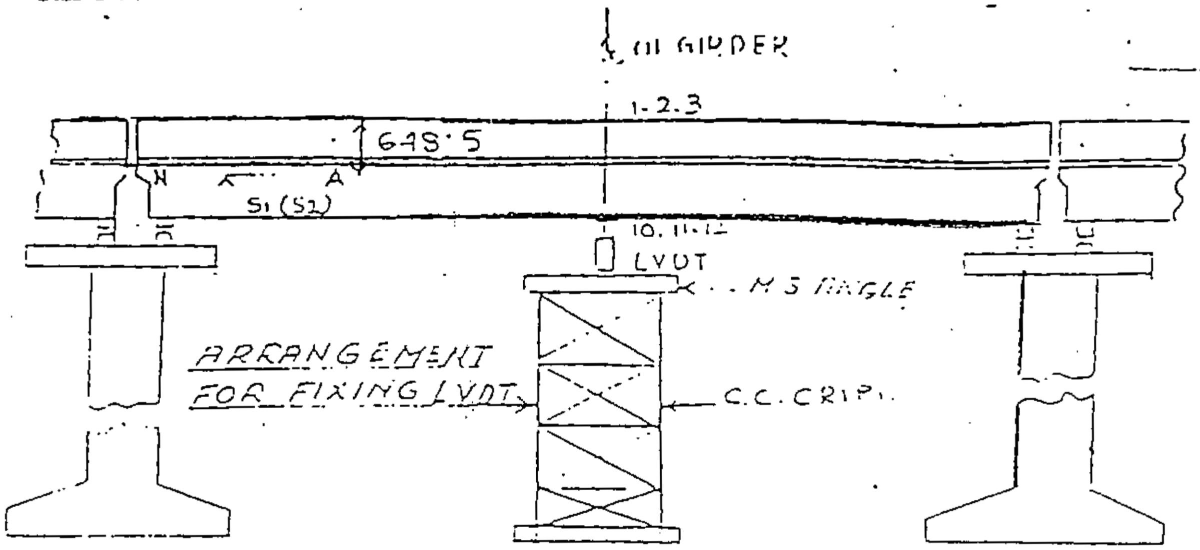
SECTION

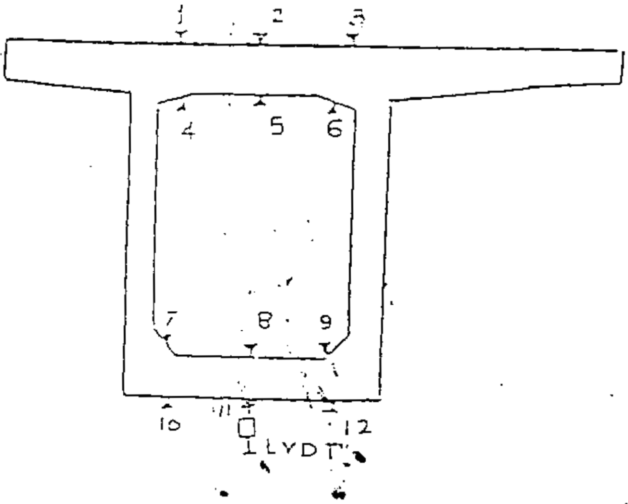
NOTE:- ALL DIMENSIONS ARE IN mm.
STRAIN GAUGE NUMBERED WITHIN BRAC
BELONGS TO (12.2) SPAN.

FIG:- 2/3

DYNAMIC EFFECTS ON PSC GIRDER BRIDGE
(2x12.2m + 3x18.3m)
DETAIL OF INSTRUMENTATION.

Location of Instrumentation of different type of bridge tested





NO OF CHANNELS

LOCATION	GAUGES	CHANNELS
TOP SLAB	6	6
BOTTOM SLAB	6	6
WHEEL MARKER	2	1
LVDT	1	1
SHEAR	4	2
	19	16

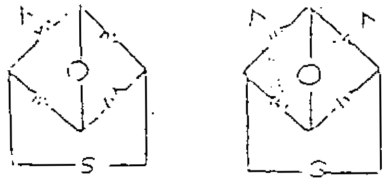
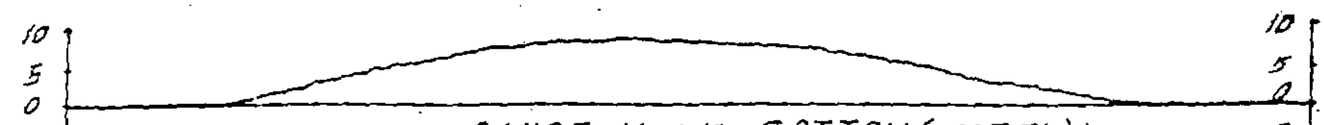


FIG :- 2/4

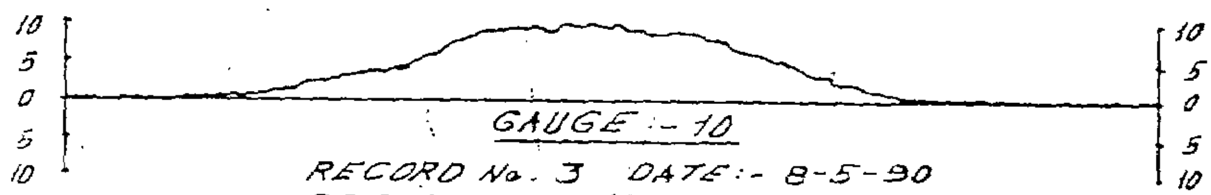
DYNAMIC EFFECT ON PSC BOX GIRDER.
BR. NO. 2/25576 ON ROHA - KHAD SEC. OF
KONKAN RLY. SPAN-2×26.226+10 CM. PSC BOX
DETAILS OF INSTRUMENTATION

Specimen oscillograms obtained during the trials for Single WDM2A locomotive at crawling and speed runs..



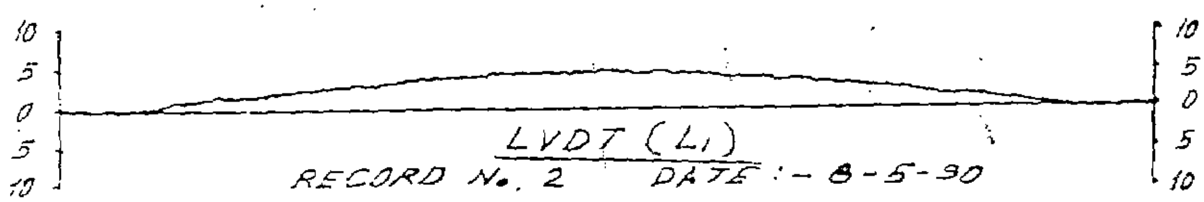
GAUGE No: 10 BOTTOM (STEEL)

RECORD No. 2 DATE :- 8-5-90
SPEED-CRAWLING
TRAIN COMPOSITION - SINGLE WDM$_2$ A



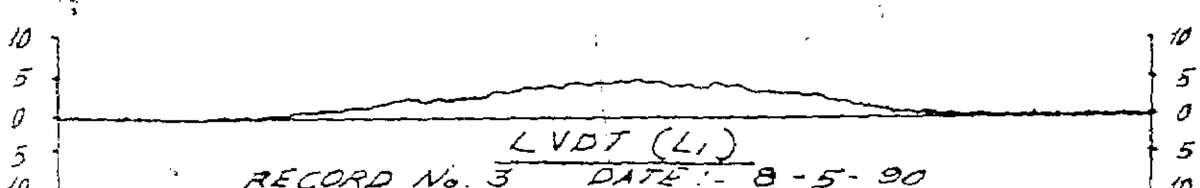
GAUGE :- 10

RECORD No. 3 DATE :- 8-5-90
SPEED 125 KMPH
TRAIN COMPOSITION - SINGLE WDM$_2$ A



LVDT (L_1)

RECORD No. 2 DATE :- 8-5-90
SPEED CRAWLING.
TRAIN COMPOSITION - SINGLE WDM$_2$ A



LVDT (L_1)

RECORD No. 3 DATE :- 8-5-90
SPEED - 125 KMPH
TRAIN COMPOSITION - SINGLE WDM$_2$ A

FIG. 3/1

DYNAMIC EFFECT ON COMPOSITE GIRDER BRIDGE No 356 (16 x 18·3 m) SPAN
TYPICAL OSCILLOGRAPH RECORDS
SINGLE WDM$_2$ A

Specimen oscillograms obtained during the trials for Coupled WDM2A locomotive at crawling and speed runs..

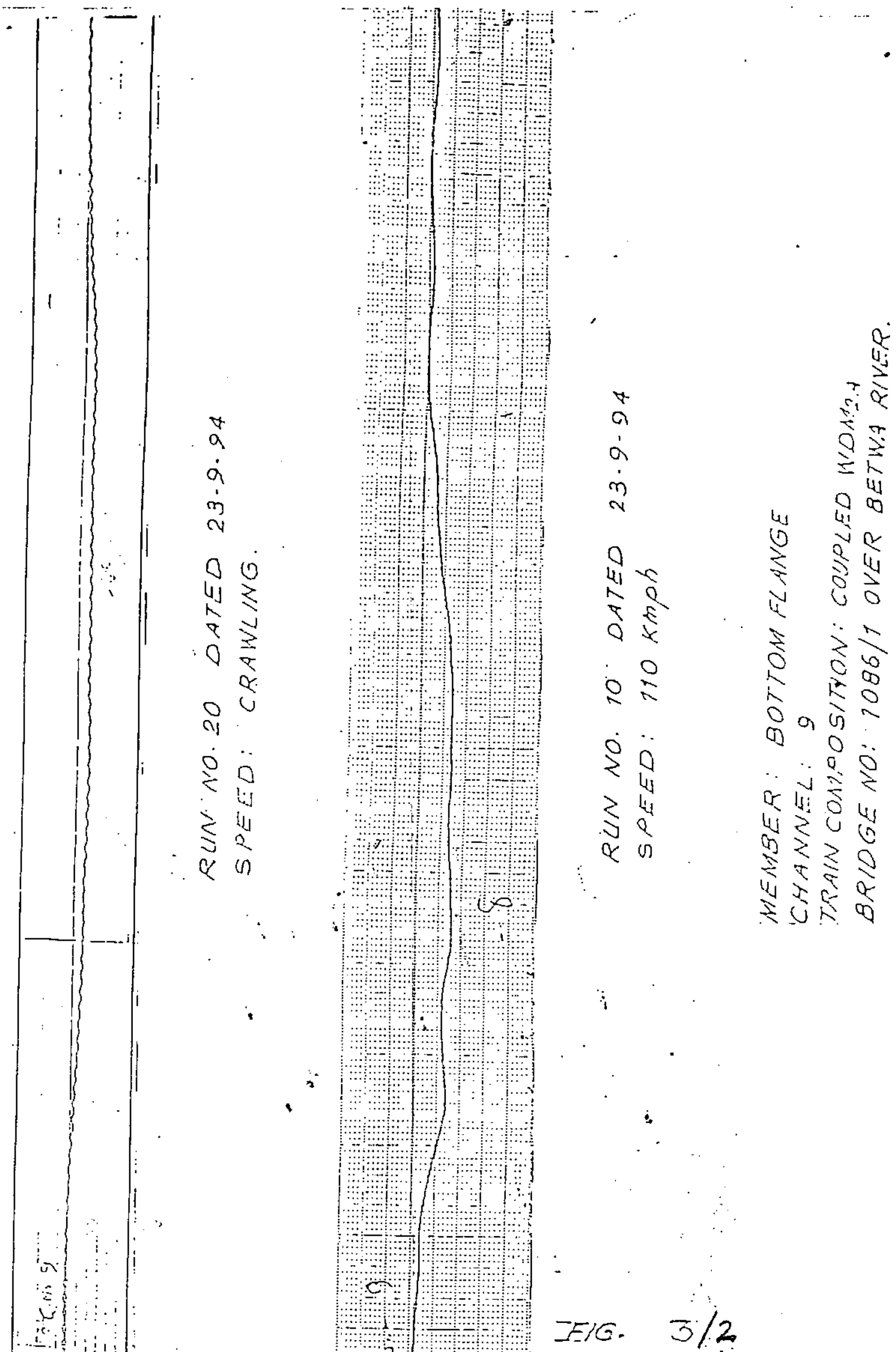


FIG. 3/2

DEFLECTION TEST ON
COMPOSITE SPAN OF 23 M.
AT BETWA BRIDGE C. RLY.
TYPICAL OSCILLOGRAM RECORD
UNDER COUPLED WDM2A

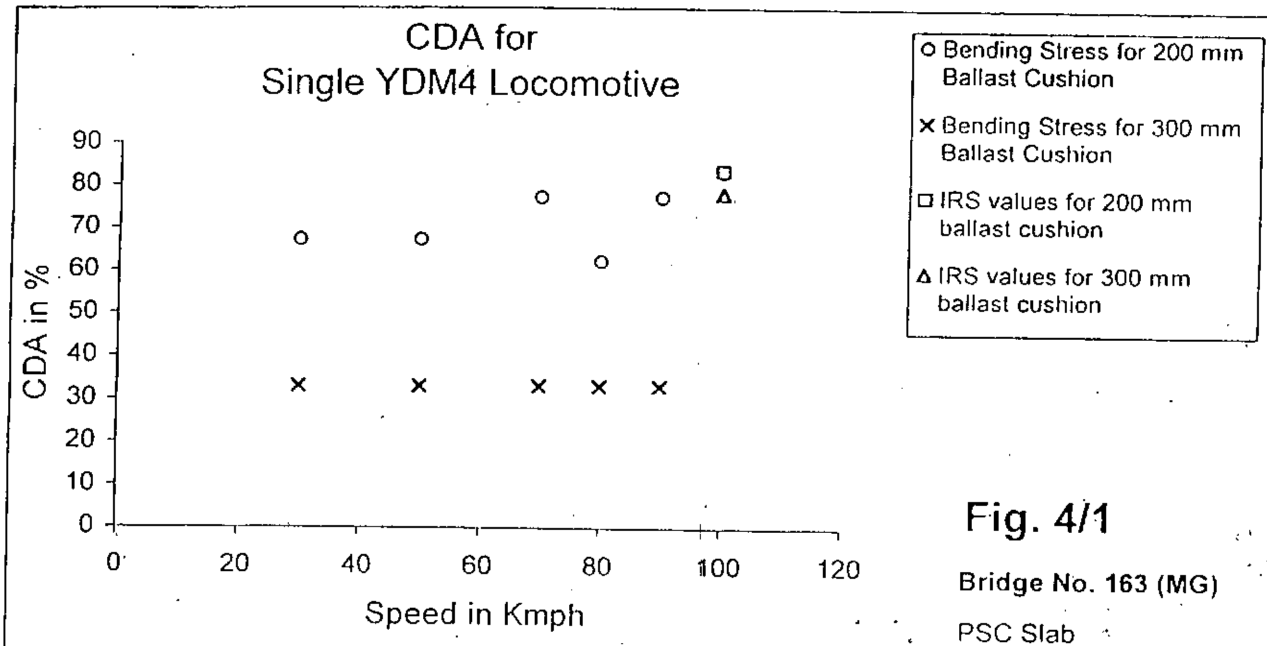


Fig. 4/1

Bridge No. 163 (MG)

PSC Slab

Span Length = 3.66 m

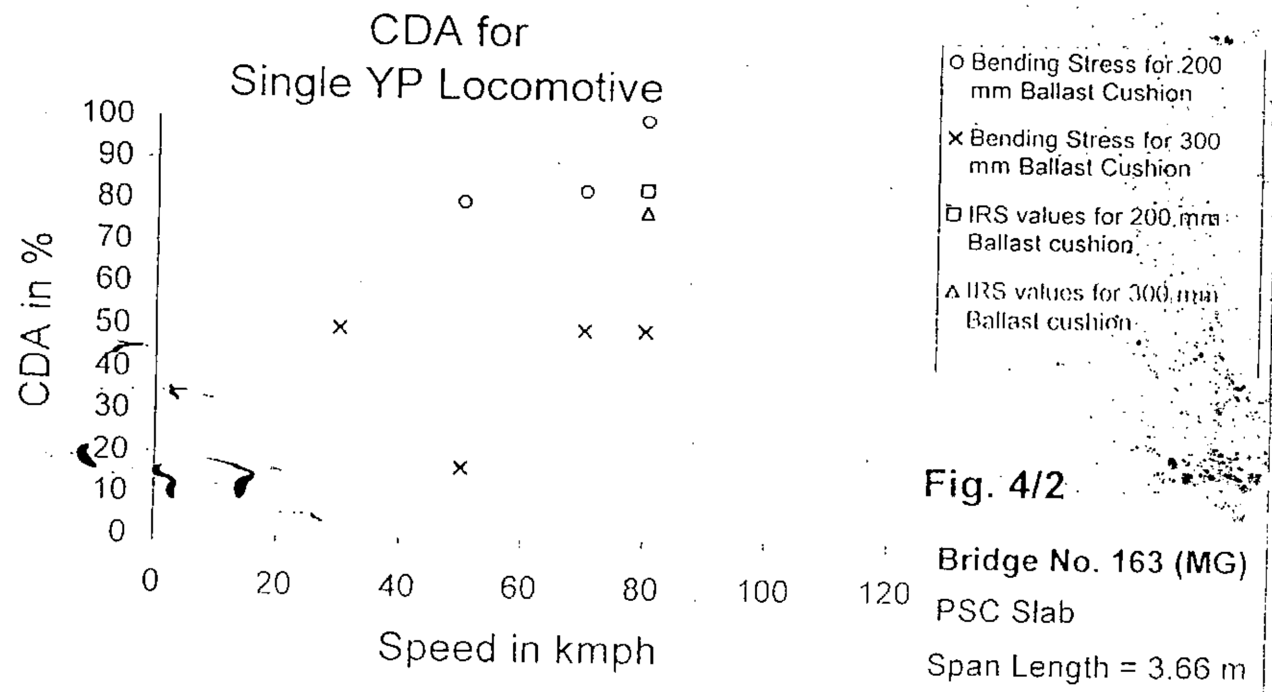


Fig. 4/2

Bridge No. 163 (MG)

PSC Slab

Span Length = 3.66 m

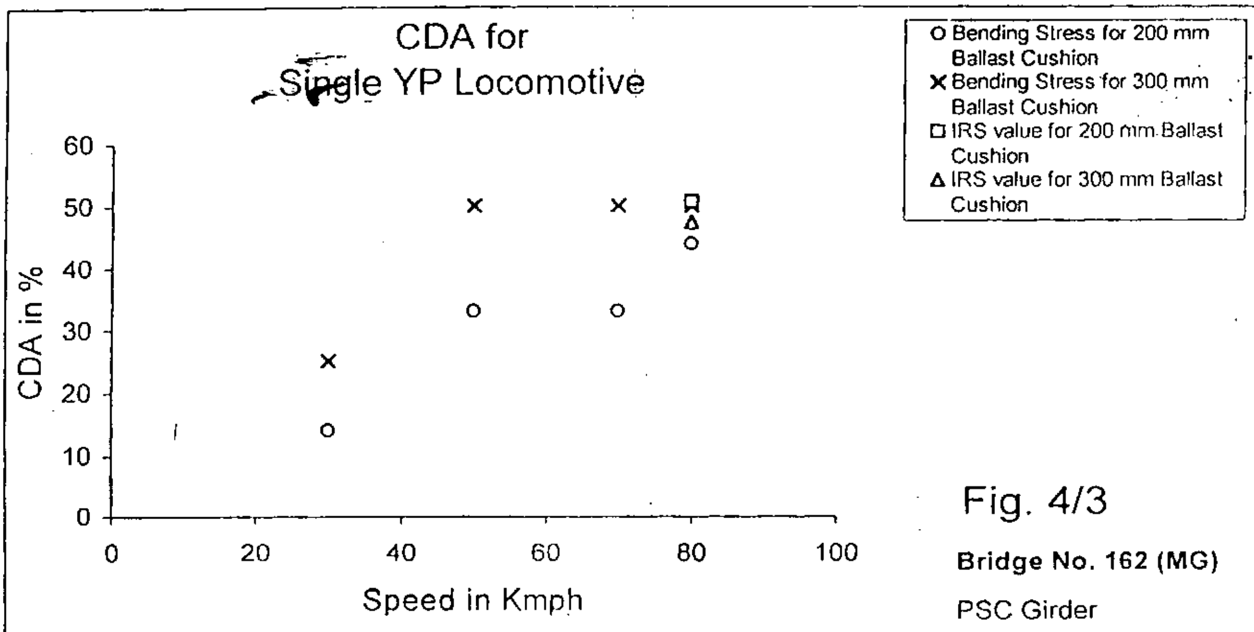


Fig. 4/3

Bridge No. 162 (MG)

PSC Girder

Span Length = 12.2 m

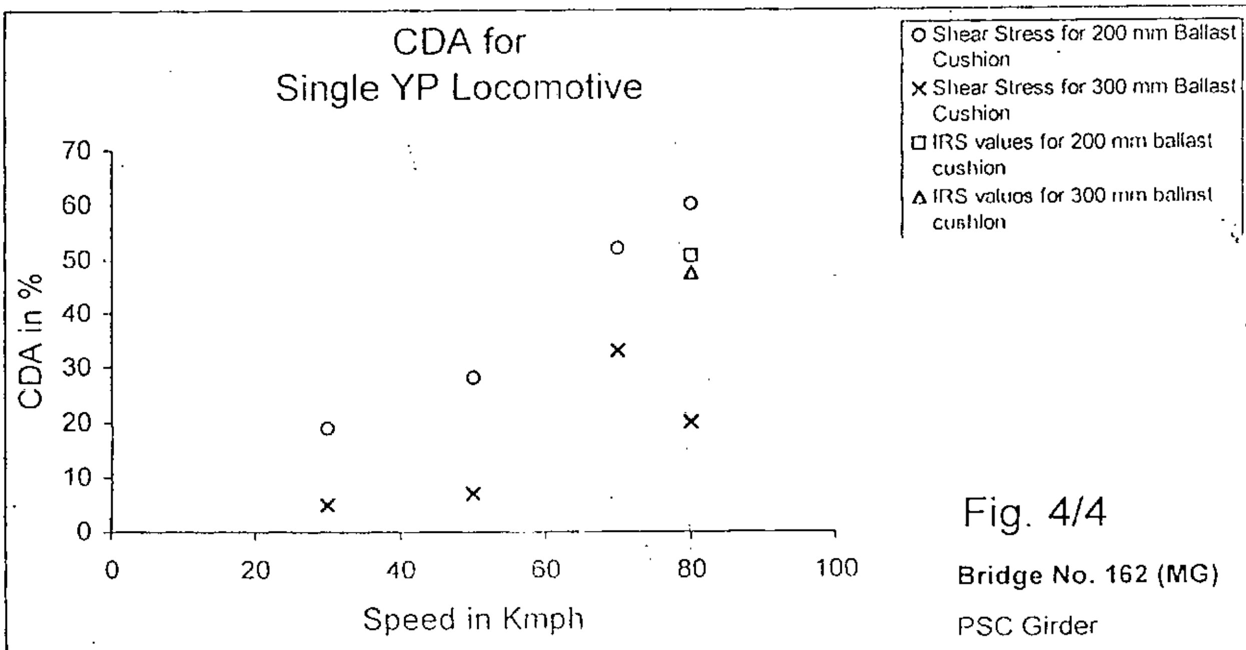


Fig. 4/4

Bridge No. 162 (MG)

PSC Girder

Span Length = 12.2 m

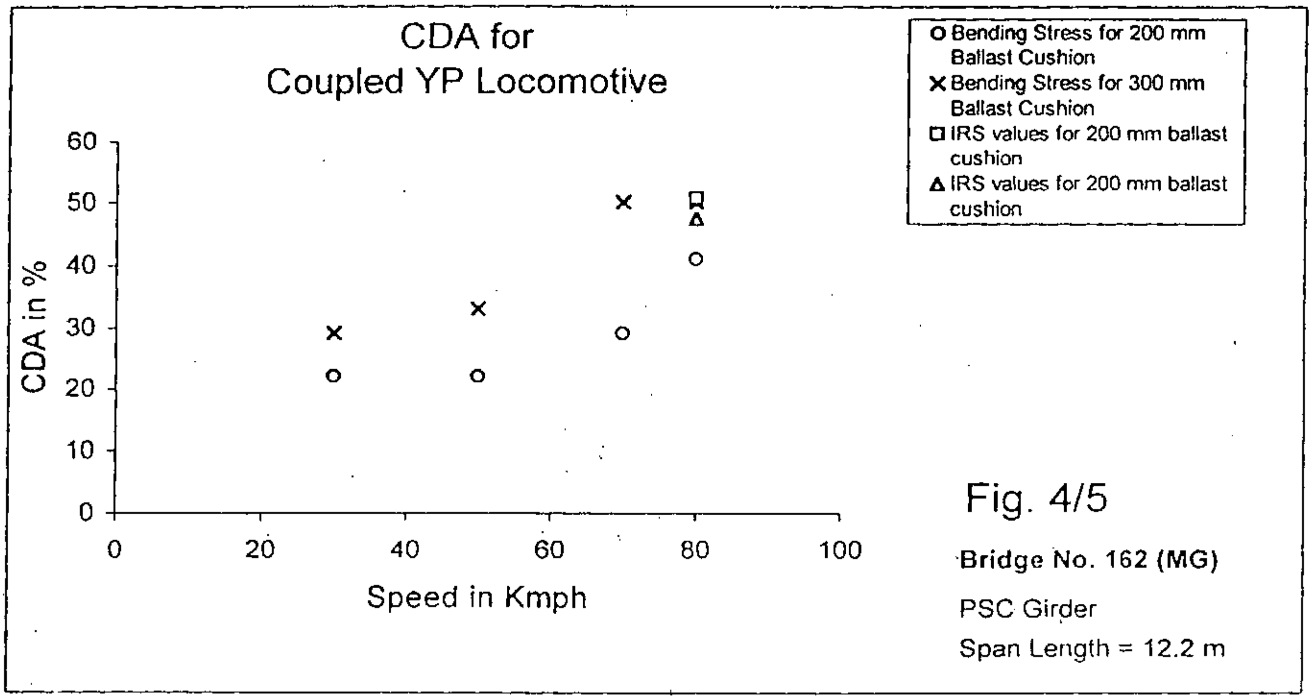


Fig. 4/5

Bridge No. 162 (MG)

PSC Girder

Span Length = 12.2 m

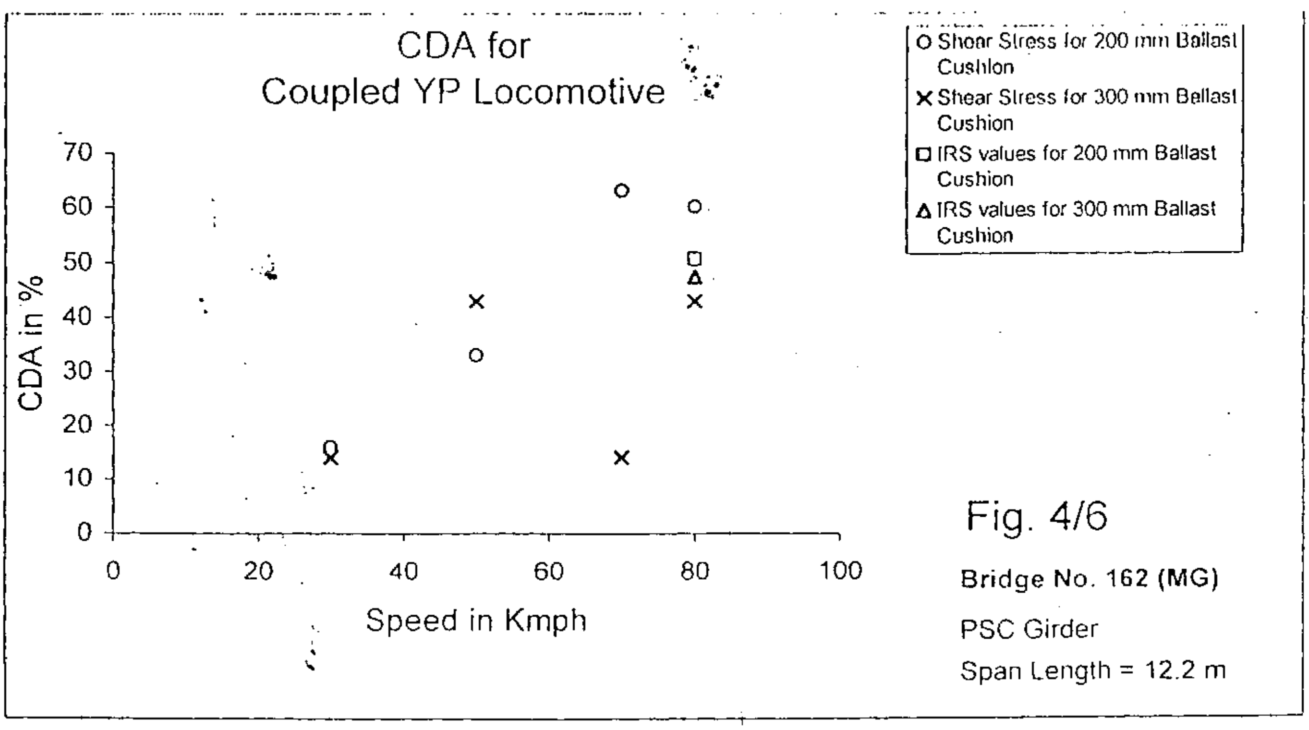


Fig. 4/6

Bridge No. 162 (MG)

PSC Girder

Span Length = 12.2 m

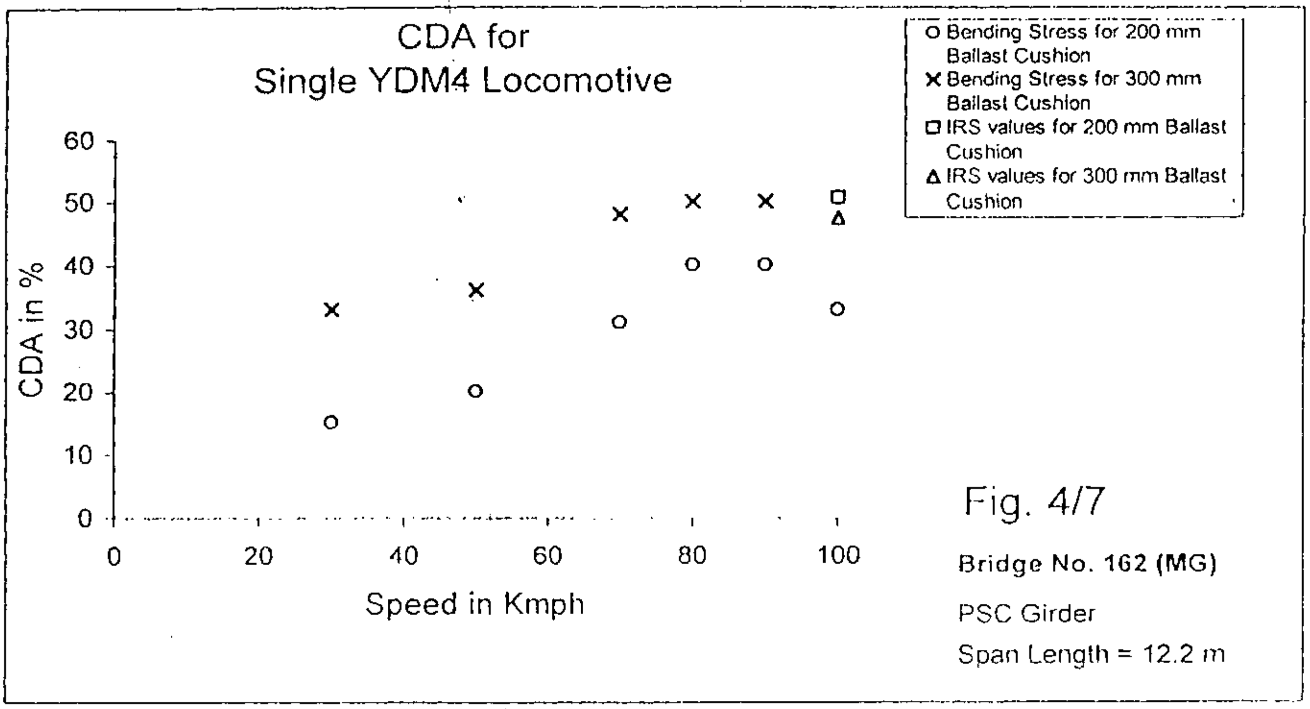


Fig. 4/7

Bridge No. 162 (MG)

PSC Girder

Span Length = 12.2 m

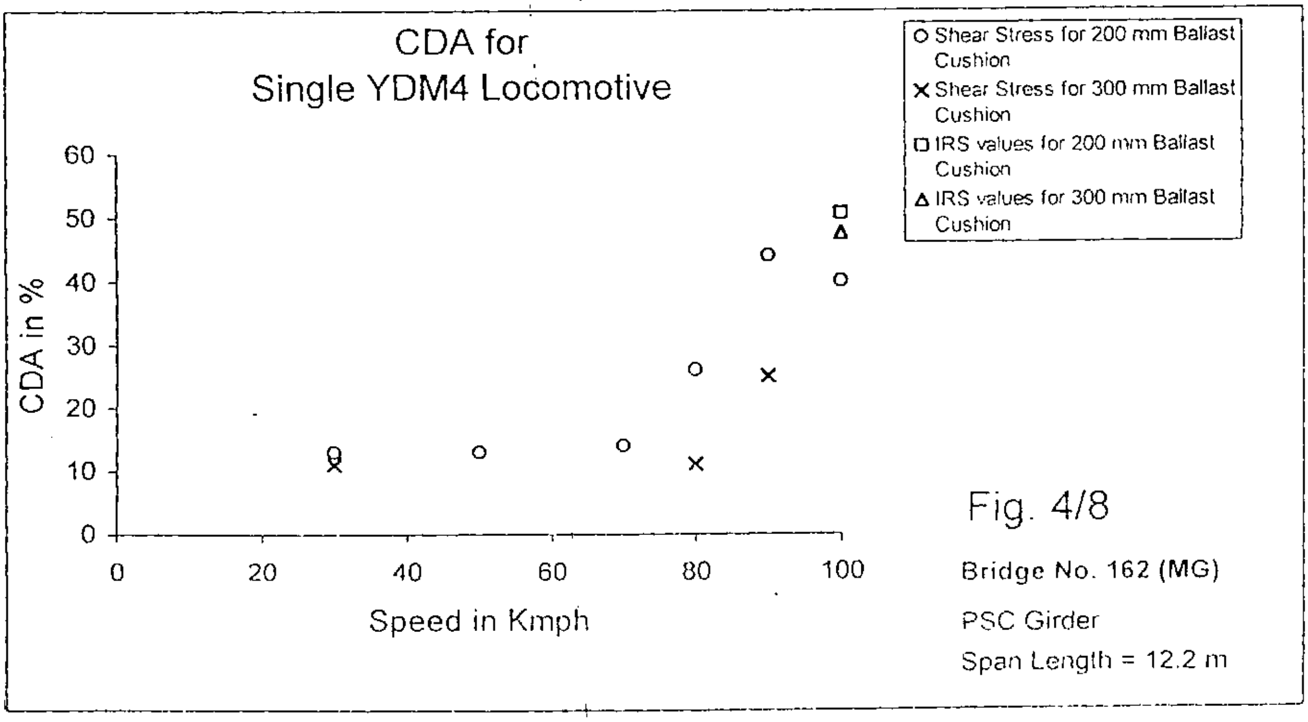


Fig. 4/8

Bridge No. 162 (MG)

PSC Girder

Span Length = 12.2 m

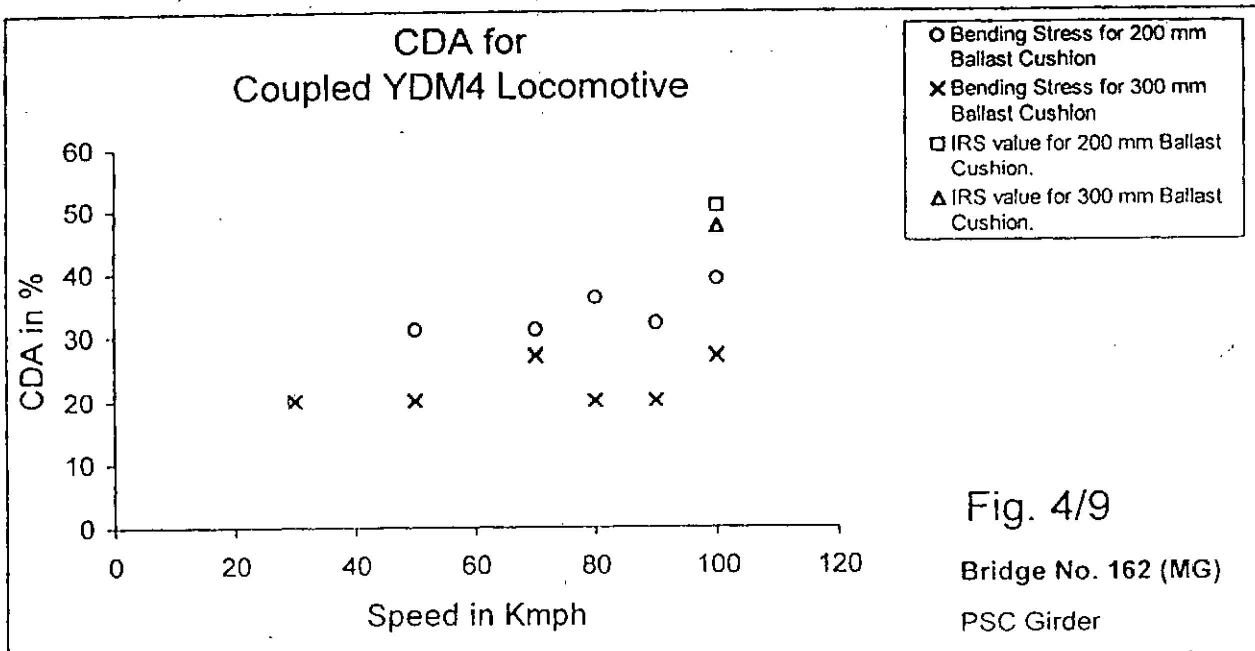


Fig. 4/9

Bridge No. 162 (MG)

PSC Girder

Span Length = 12.2 m

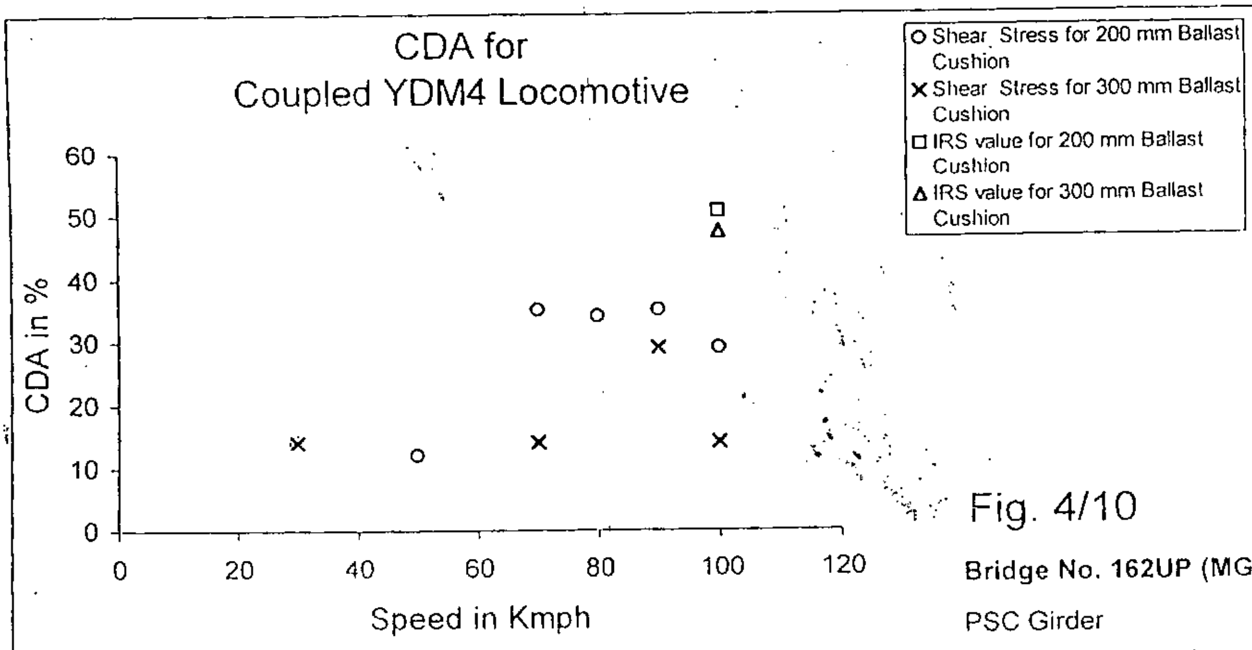


Fig. 4/10

Bridge No. 162UP (MG)

PSC Girder

Span Length = 12.2 m

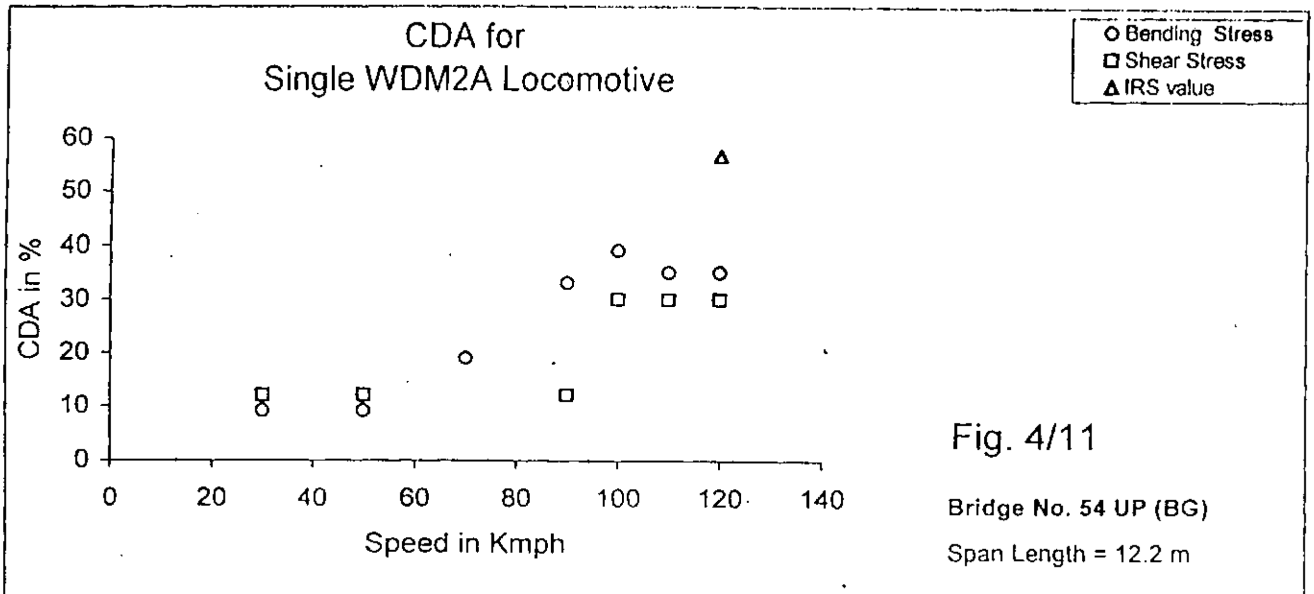


Fig. 4/11

Bridge No. 54 UP (BG)

Span Length = 12.2 m

Ballast cushion 200 mm

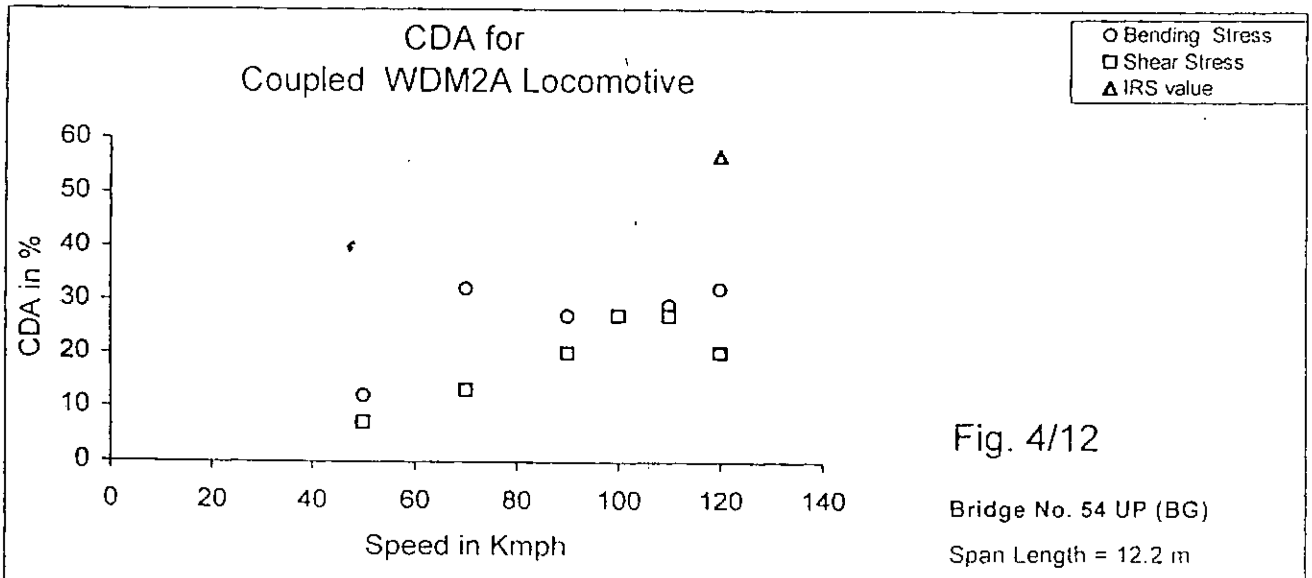


Fig. 4/12

Bridge No. 54 UP (BG)

Span Length = 12.2 m

Ballast cushion 200 mm

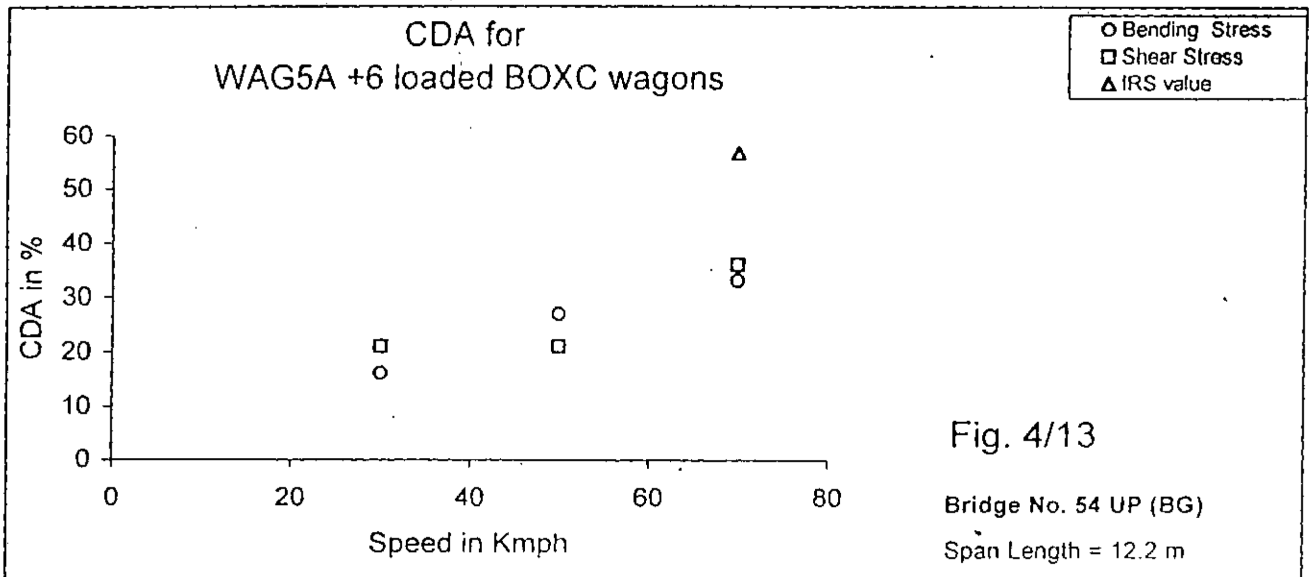


Fig. 4/13

Bridge No. 54 UP (BG)

Span Length = 12.2 m

Ballast cushion 200 mm

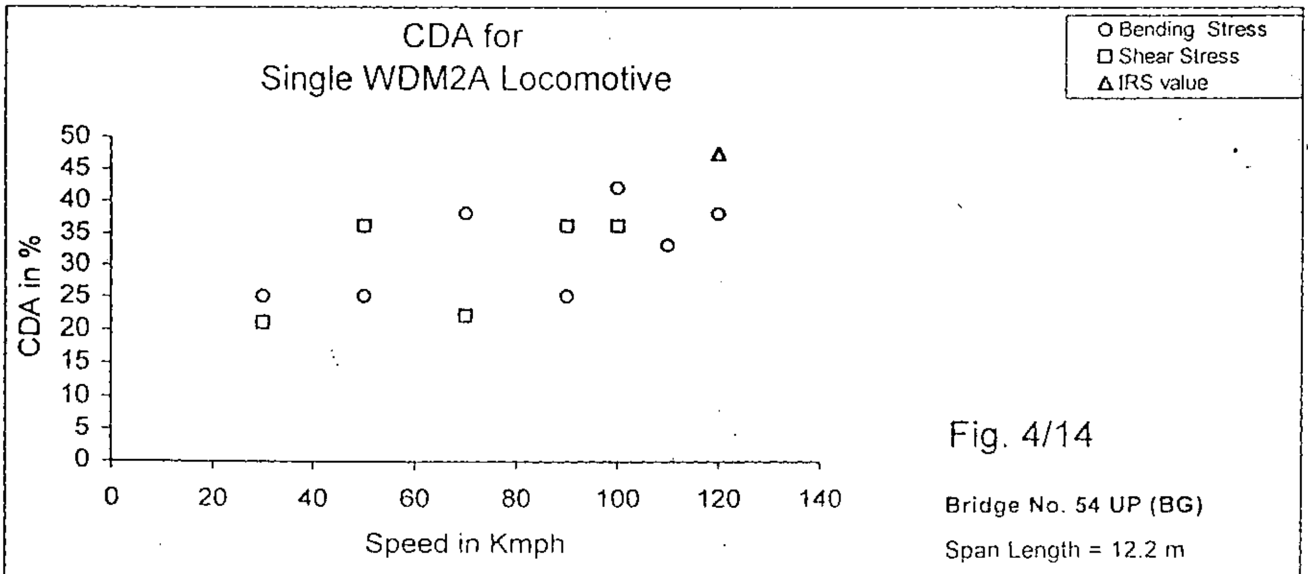


Fig. 4/14

Bridge No. 54 UP (BG)

Span Length = 12.2 m

Ballast cushion 300 mm

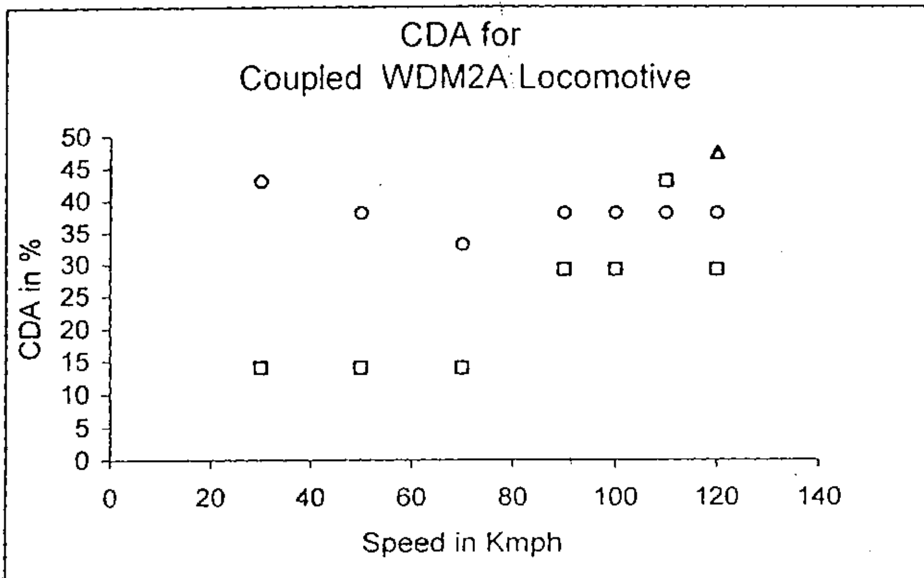


Fig. 4/15

Bridge No. 54 UP (BG)

Span Length = 12.2 m

Ballast cushion 300 mm

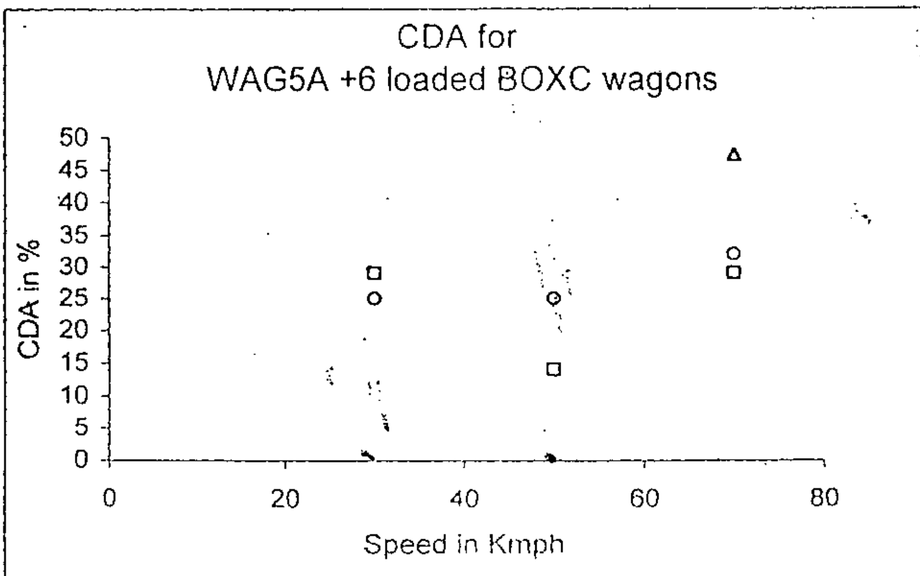


Fig. 4/16

Bridge No. 54 UP (BG)

Span Length = 12.2 m

Ballast cushion 300 mm

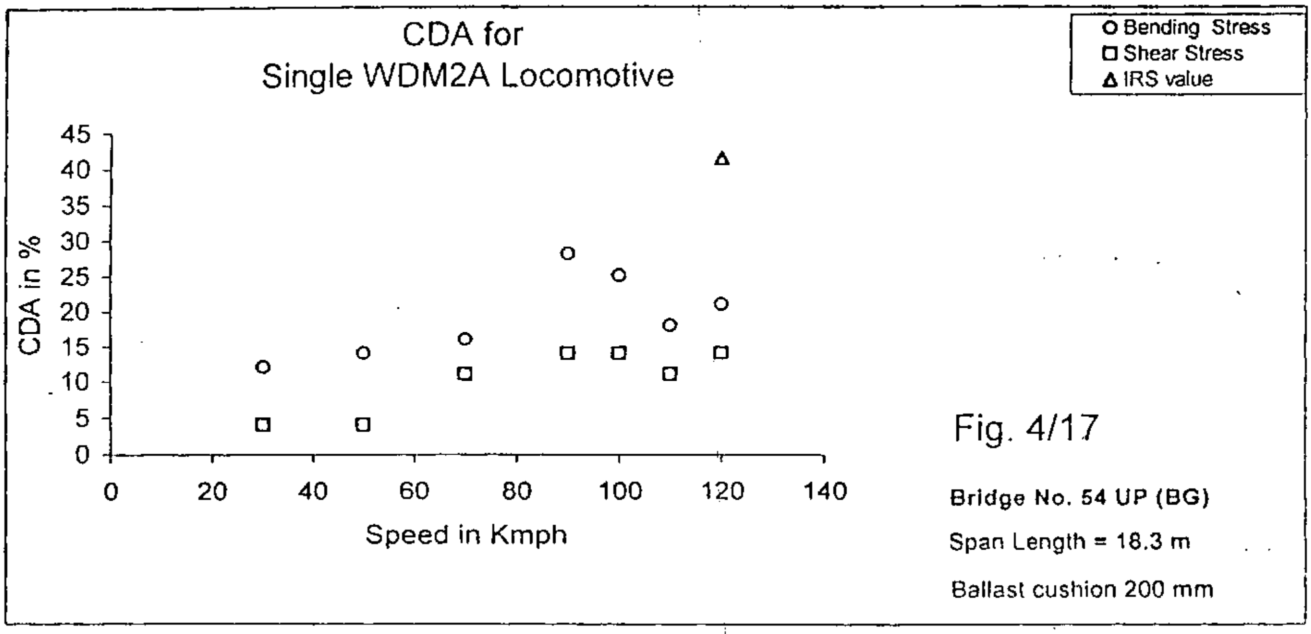


Fig. 4/17

Bridge No. 54 UP (BG)

Span Length = 18.3 m

Ballast cushion 200 mm

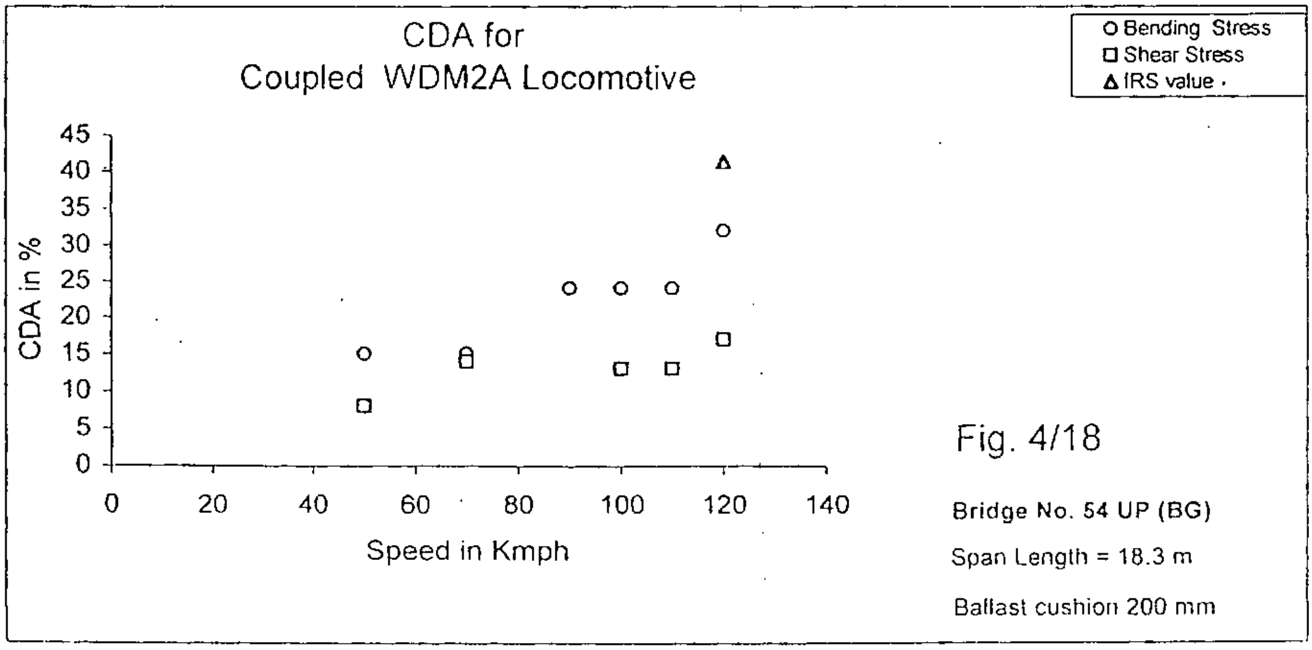


Fig. 4/18

Bridge No. 54 UP (BG)

Span Length = 18.3 m

Ballast cushion 200 mm

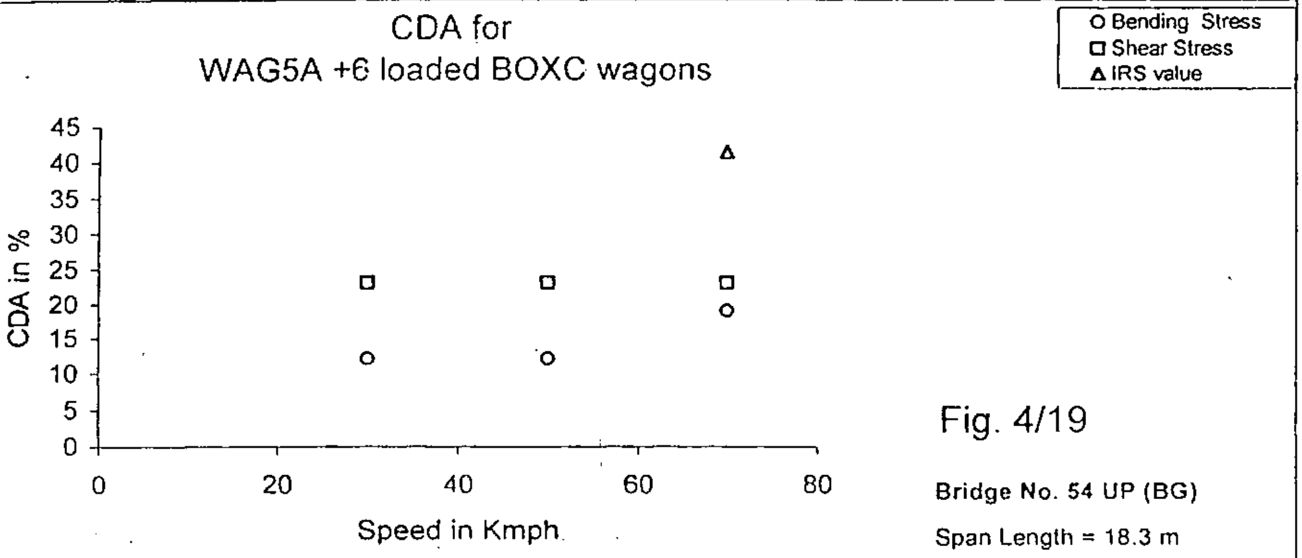


Fig. 4/19

Bridge No. 54 UP (BG)

Span Length = 18.3 m

Ballast cushion 200 mm

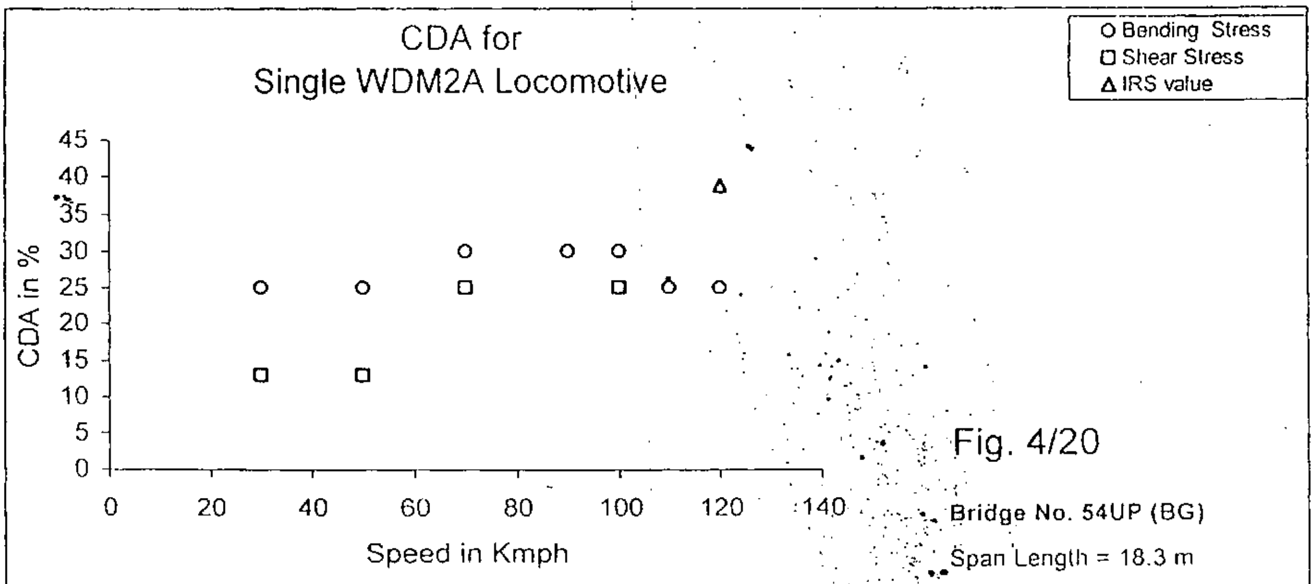


Fig. 4/20

Bridge No. 54UP (BG)

Span Length = 18.3 m

Ballast cushion 300 mm

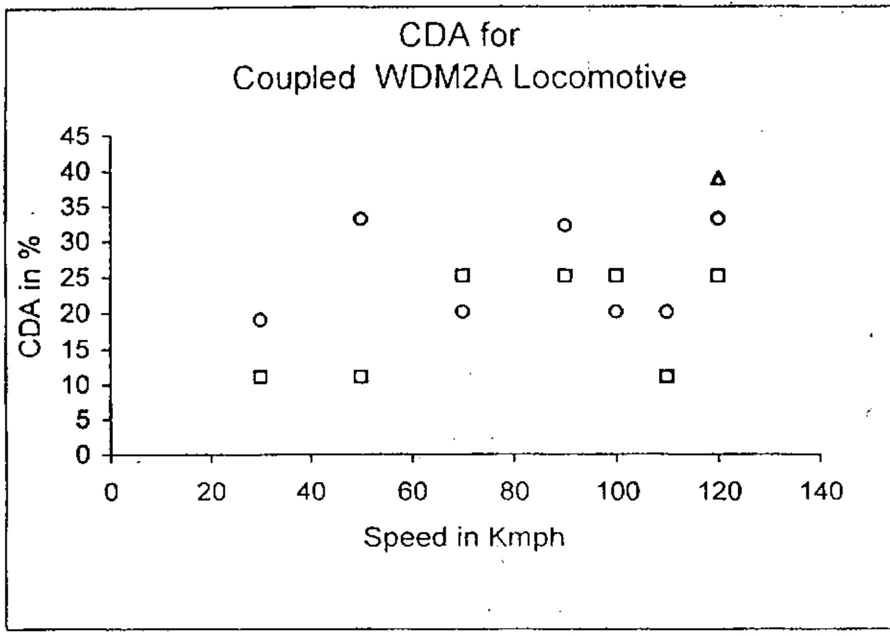


Fig. 4/21

Bridge No. 54 UP (BG)

Span Length = 18.3 m

Ballast cushion 300 mm

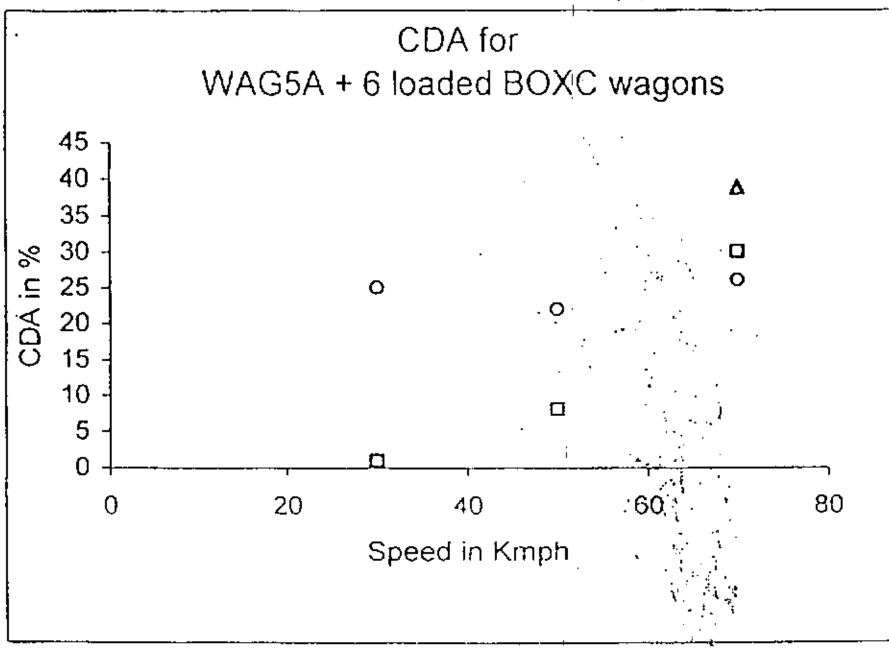


Fig. 4/22

Bridge No. 54 UP (BG)

Span Length = 18.3 m

Ballast cushion 300 mm

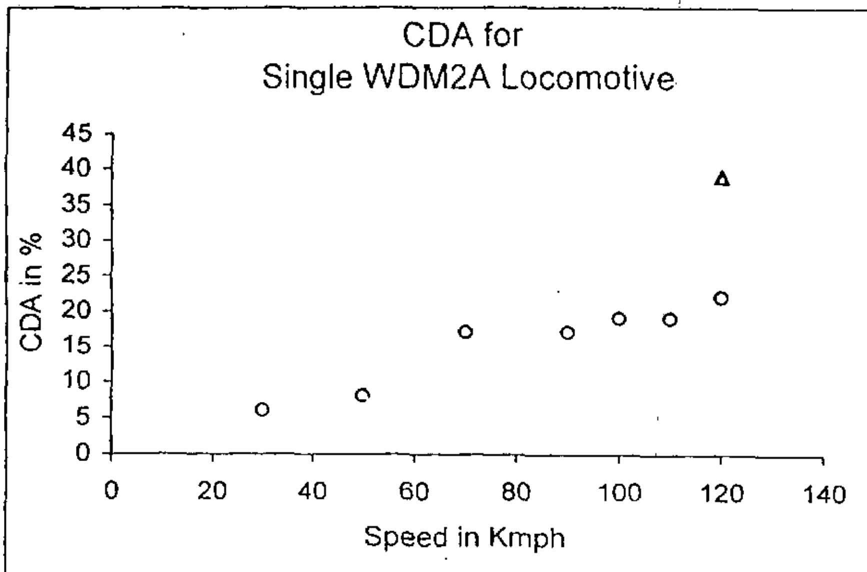


Fig. 4/23

Bridge No. 356 (BG)

Span Length = 18.3 m

Ballast cushion 300 mm

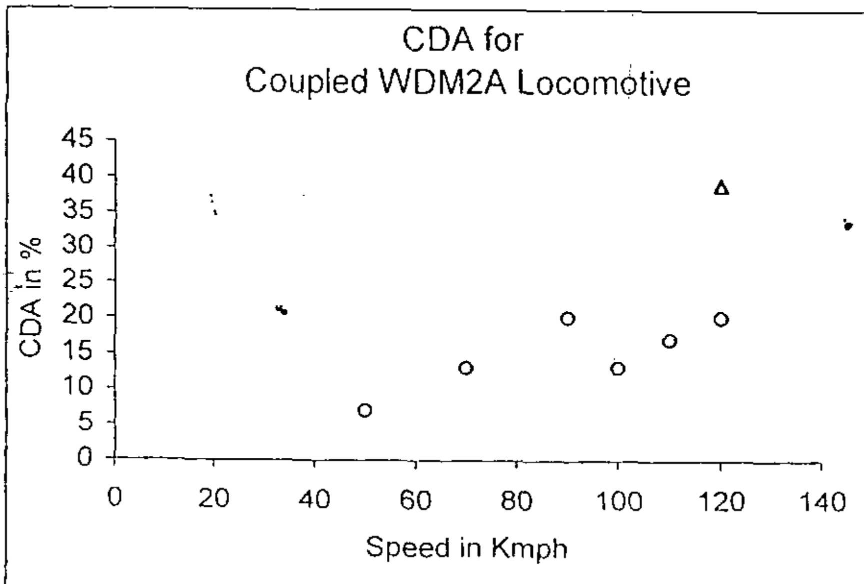


Fig. 4/24

Bridge No. 356 (BG)

Span Length = 18.3 m

Ballast cushion 300 mm

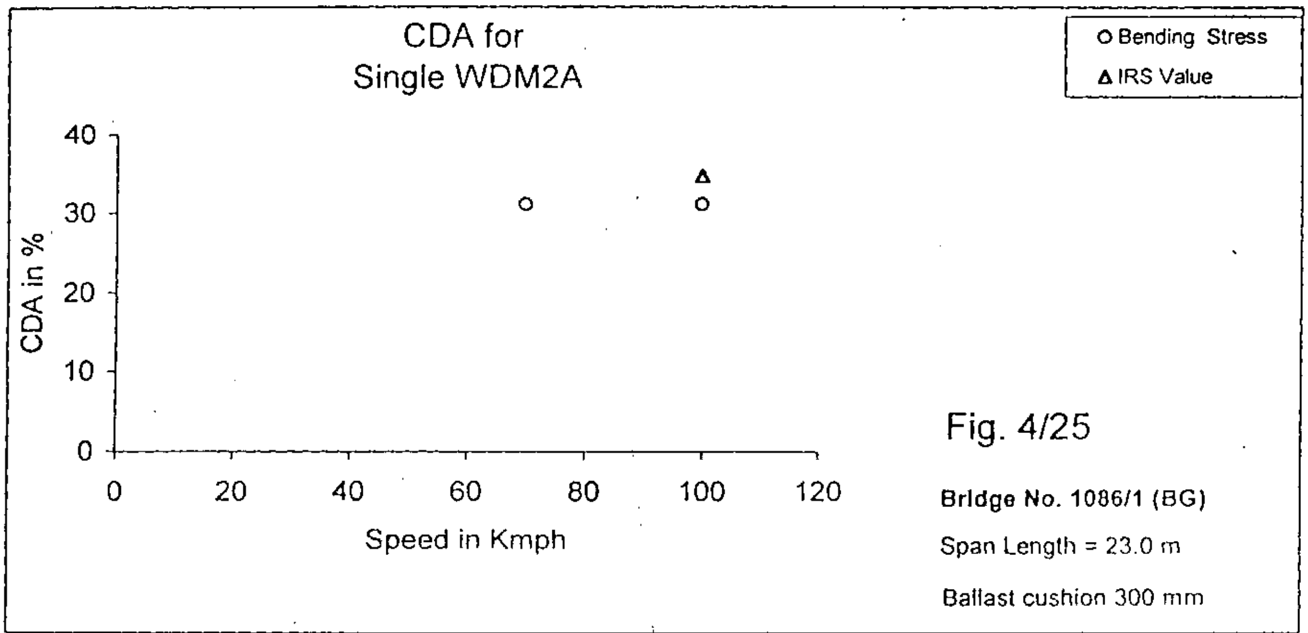


Fig. 4/25

Bridge No. 1086/1 (BG)

Span Length = 23.0 m

Ballast cushion 300 mm

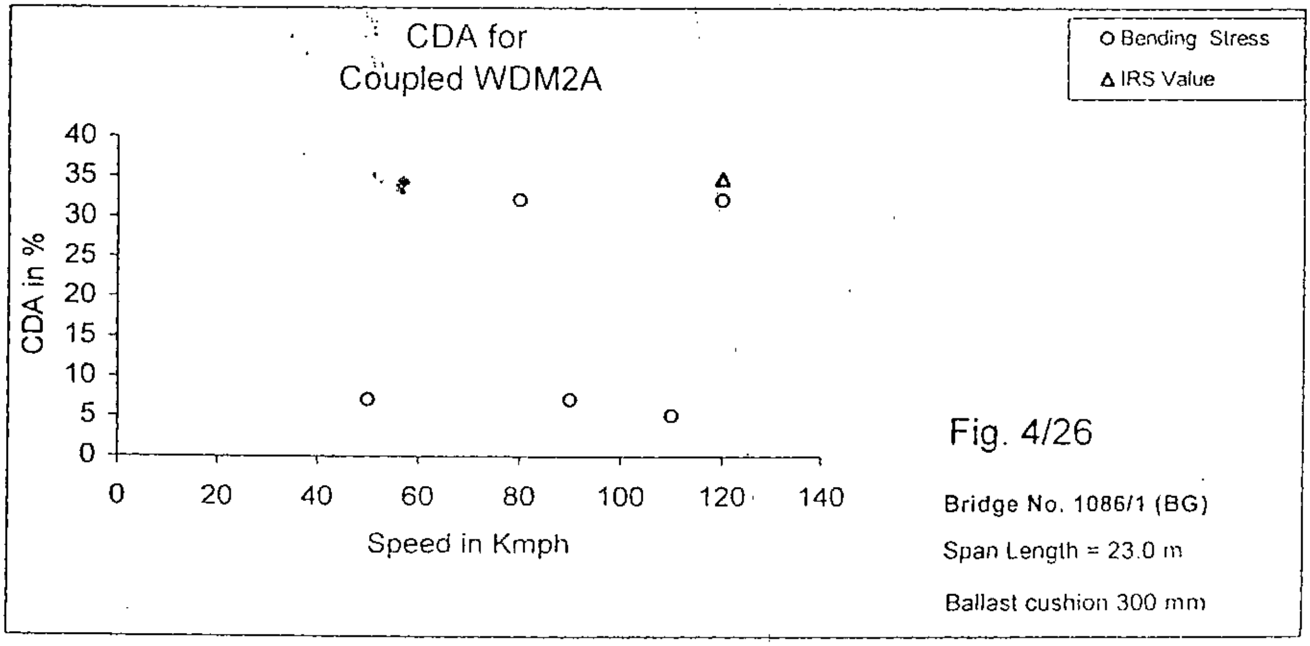


Fig. 4/26

Bridge No. 1086/1 (BG)

Span Length = 23.0 m

Ballast cushion 300 mm

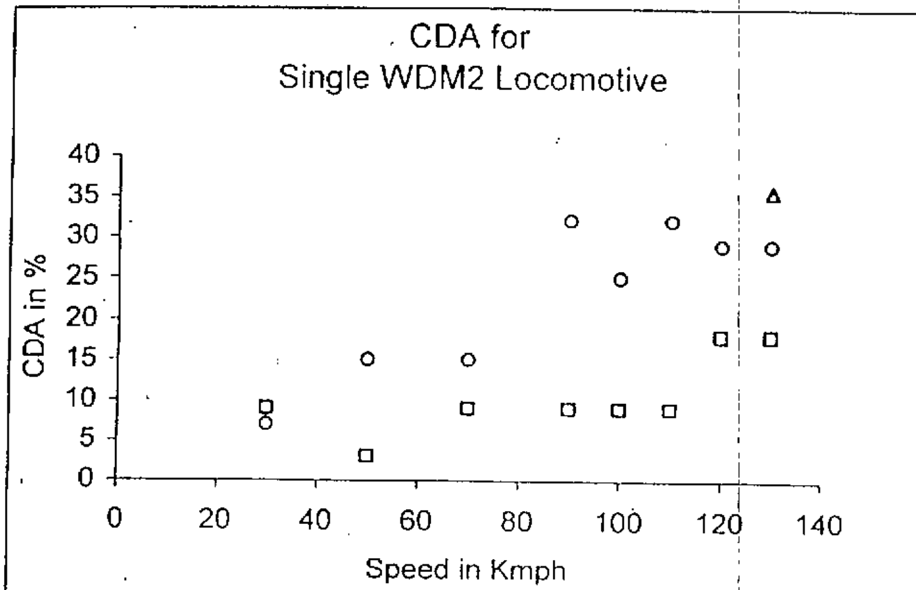


Fig. 4/27

Bridge No. 2/25576 (BG)

Span Length = 23.0 m

Ballast cushion 250 mm

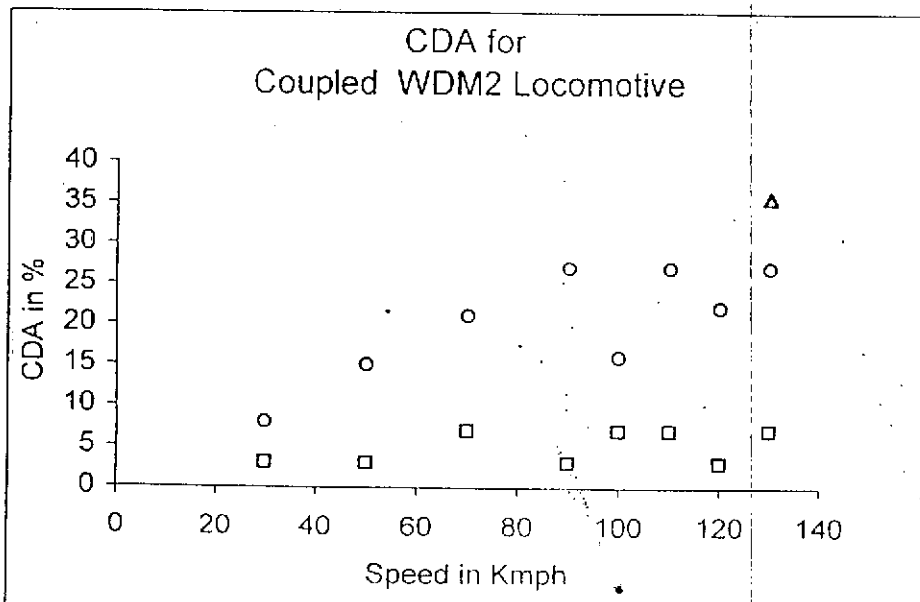


Fig. 4/28

Bridge No. 2/25576 (BG)

Span Length = 23.0 m

Ballast cushion 250 mm

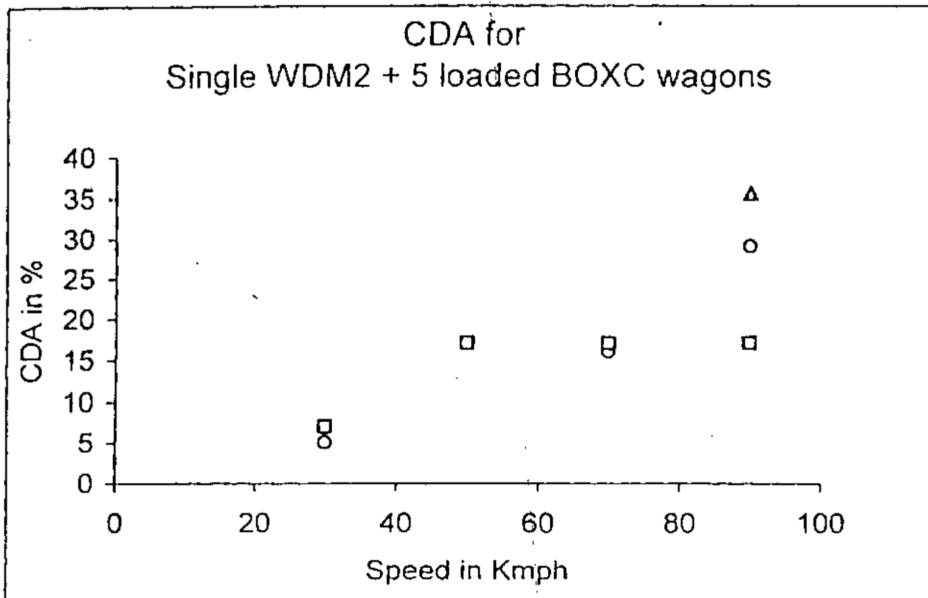


Fig. 4/29

Bridge No. 2/25576 (BG)

Span Length = 23.0 m

Ballast cushion 250 mm

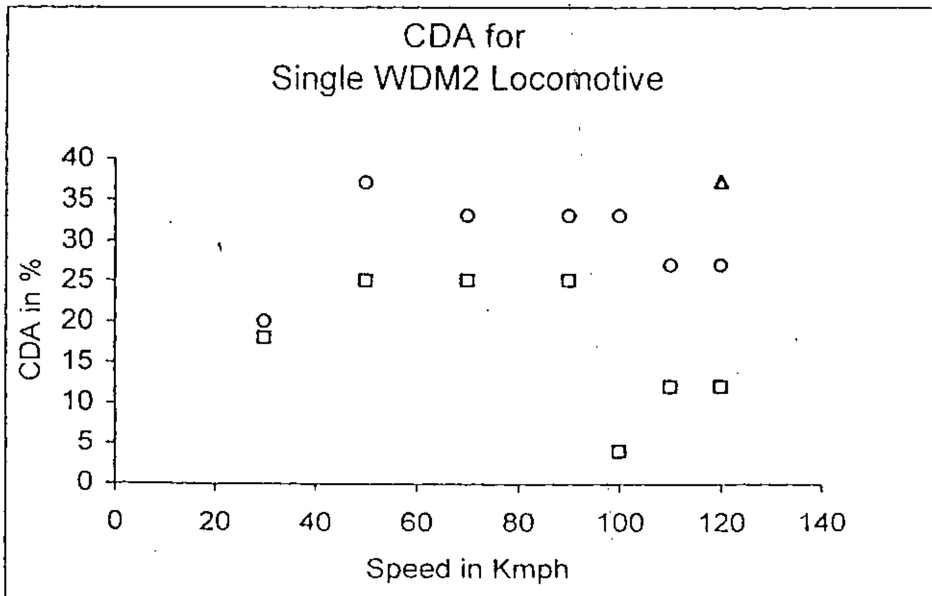


Fig. 4/30

Bridge No. 627 (BG)

Span Length = 30.0 m

Ballast cushion 250 mm

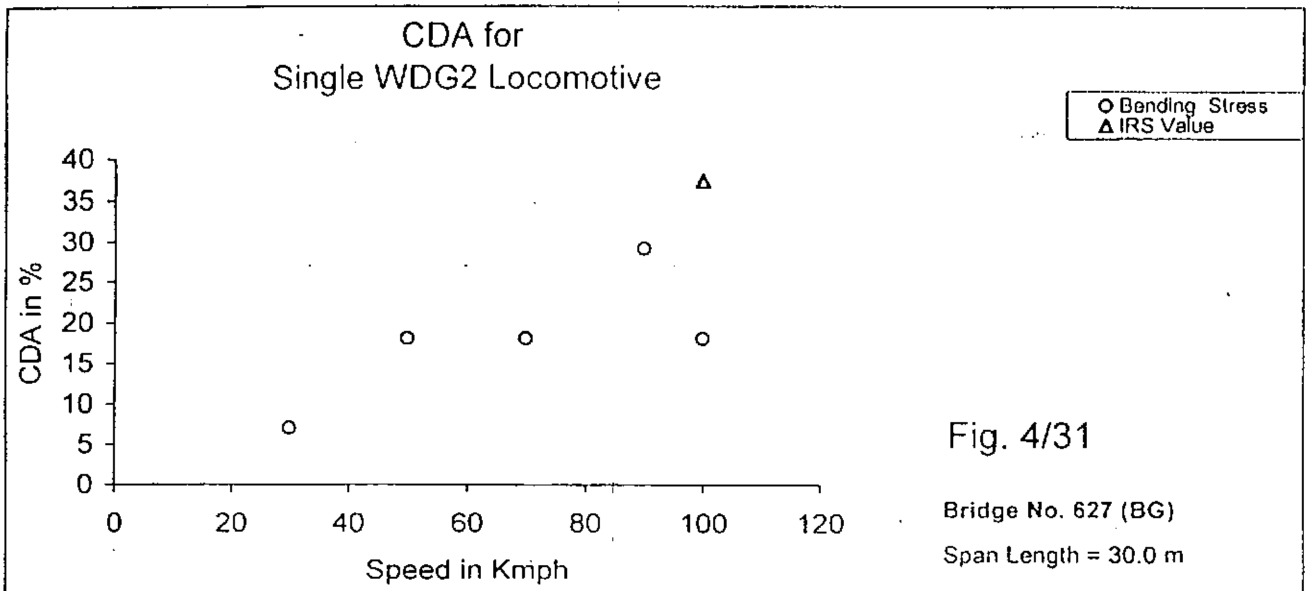


Fig. 4/31

Bridge No. 627 (BG)

Span Length = 30.0 m

Ballast cushion 250 mm

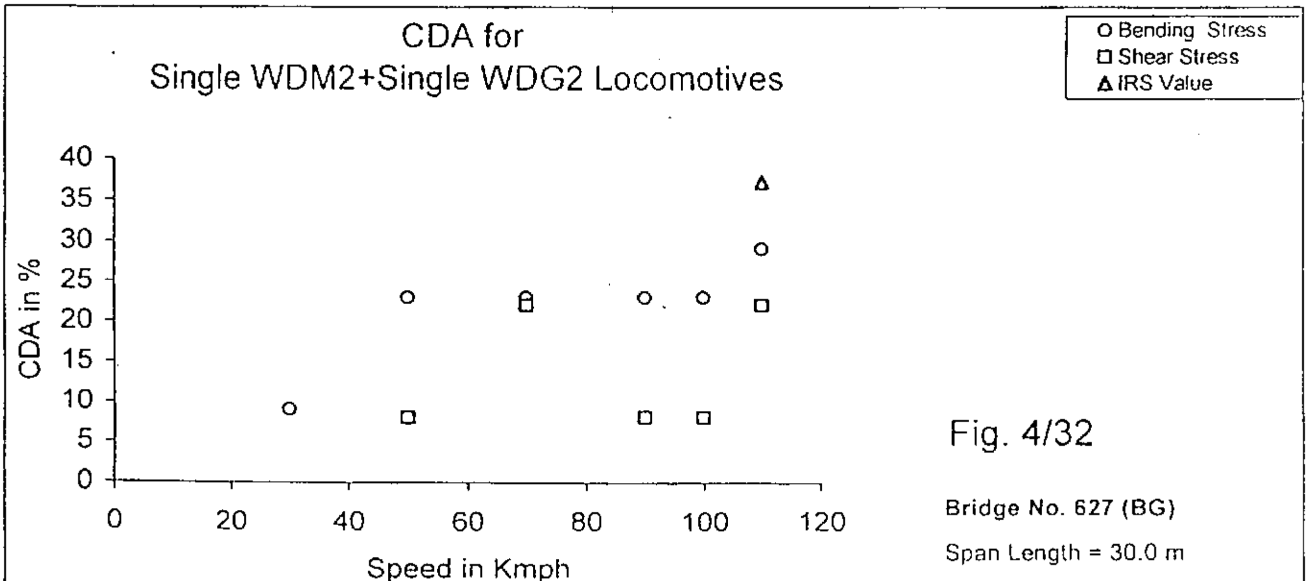
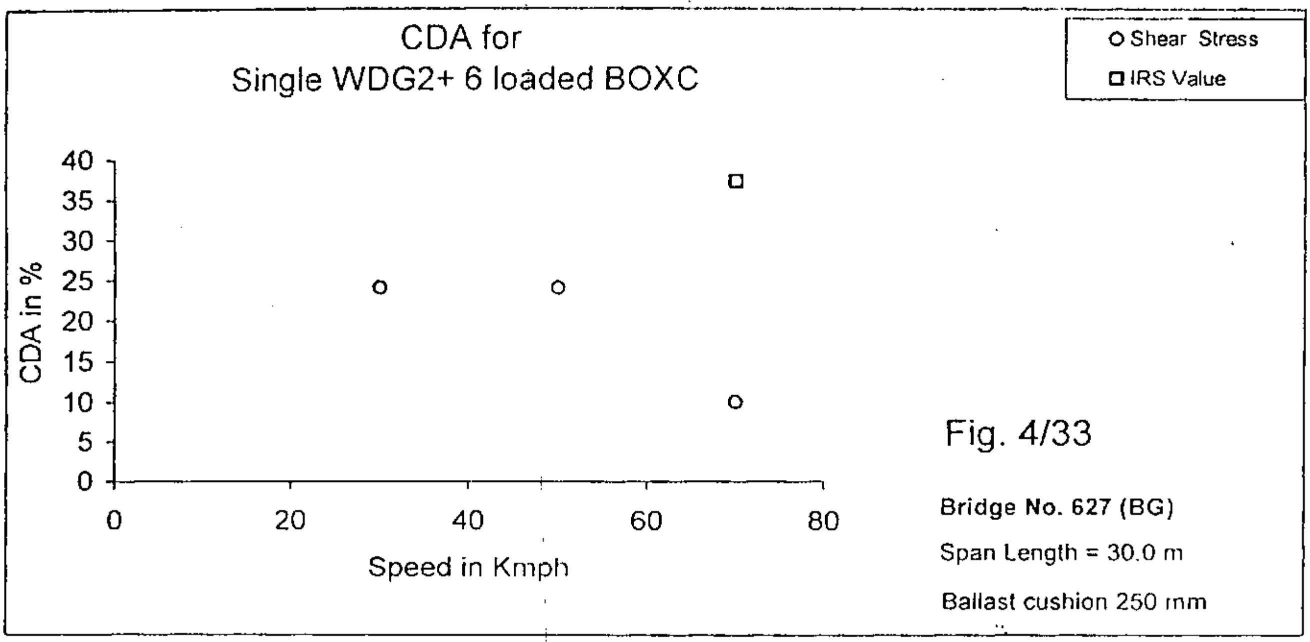


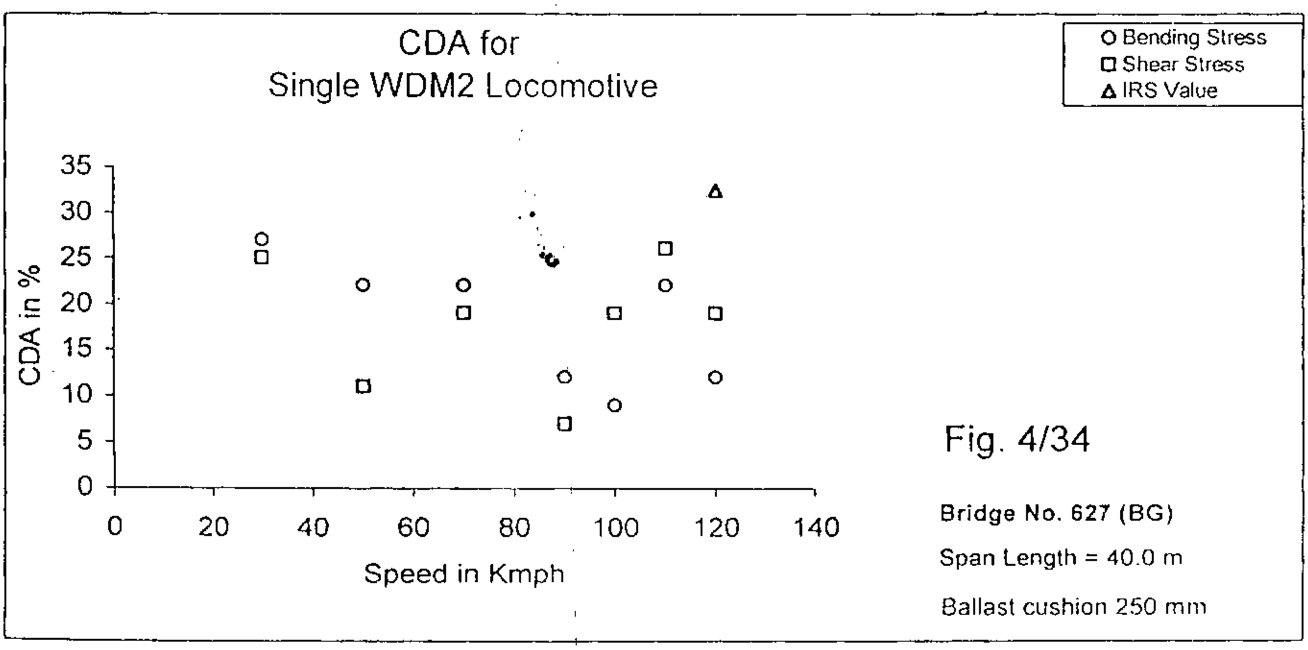
Fig. 4/32

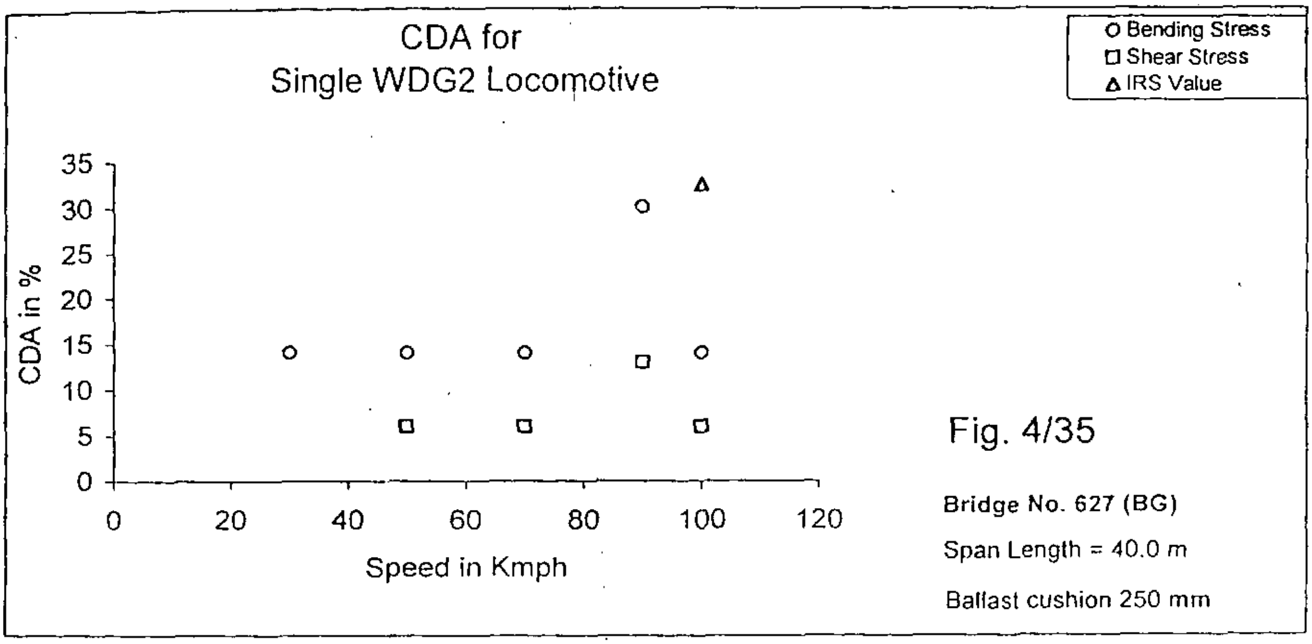
Bridge No. 627 (BG)

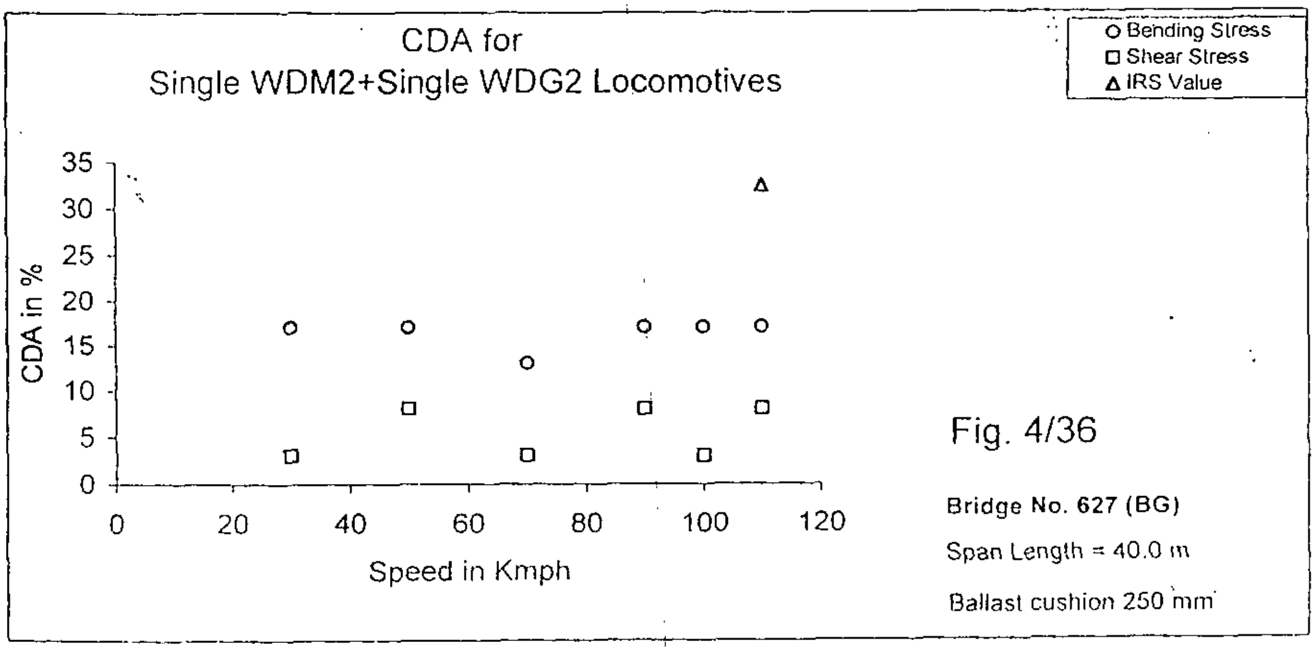
Span Length = 30.0 m

Ballast cushion 250 mm


CDA for
Single WDG2+ 6 loaded BOXC
Shear Stress
IRS Value
CDA in %
40
35
30
25
20
15
10
5
0
0
20
40
60
80
Speed in Kmph
Fig. 4/33
Bridge No. 627 (BG)
Span Length = 30.0 m
Ballast cushion 250 mm


CDA for
Single WDM2 Locomotive
Bending Stress
Shear Stress
IRS Value
CDA in %
35
30
25
20
15
10
5
0
0
20
40
60
80
100
120
140
Speed in Kmph
Fig. 4/34
Bridge No. 627 (BG)
Span Length = 40.0 m
Ballast cushion 250 mm


CDA for
Single WDG2 Locomotive
O Bending Stress
□ Shear Stress
Δ IRS Value
35
30
25
20
15
10
5
0
CDA in %
0
20
40
60
80
100
120
Speed in Kmph
Fig. 4/35
Bridge No. 627 (BG)
Span Length = 40.0 m
Ballast cushion 250 mm


CDA for
Single WDM2+Single WDG2 Locomotives
O Bending Stress
□ Shear Stress
Δ IRS Value
35
30
25
20
15
10
5
0
CDA in %
0
20
40
60
80
100
120
Speed in Kmph
Fig. 4/36
Bridge No. 627 (BG)
Span Length = 40.0 m
Ballast cushion 250 mm

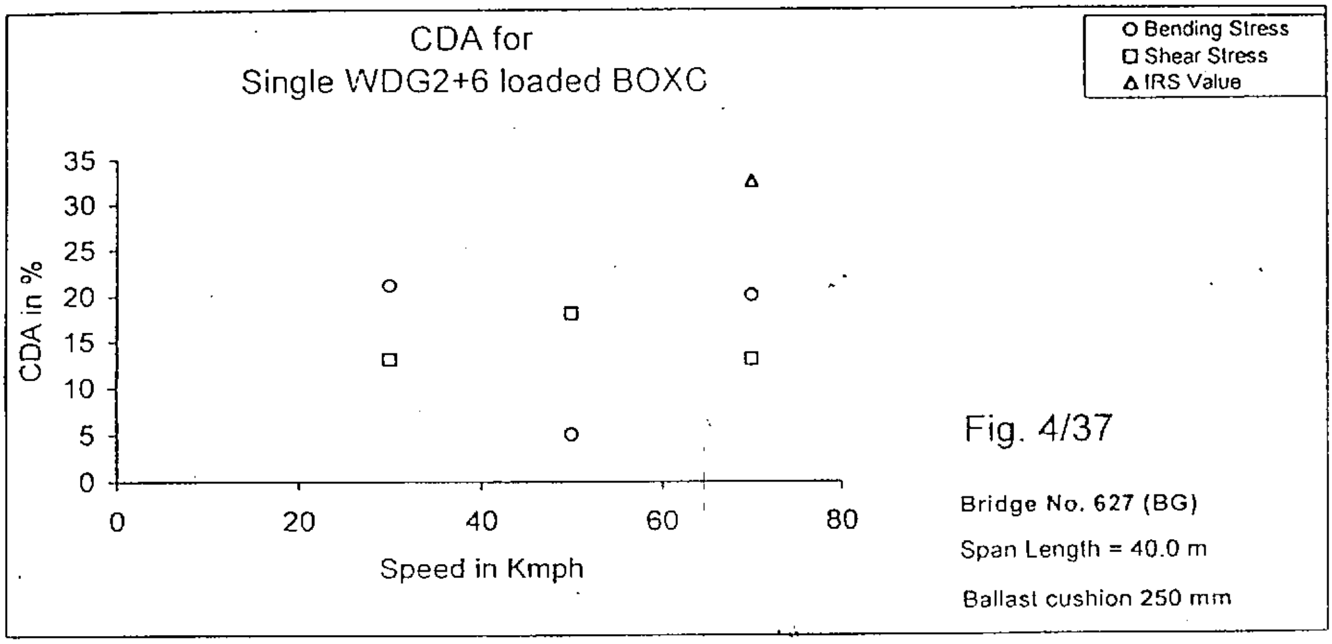


Fig. 4/37

Bridge No. 627 (BG)

Span Length = 40.0 m

Ballast cushion 250 mm

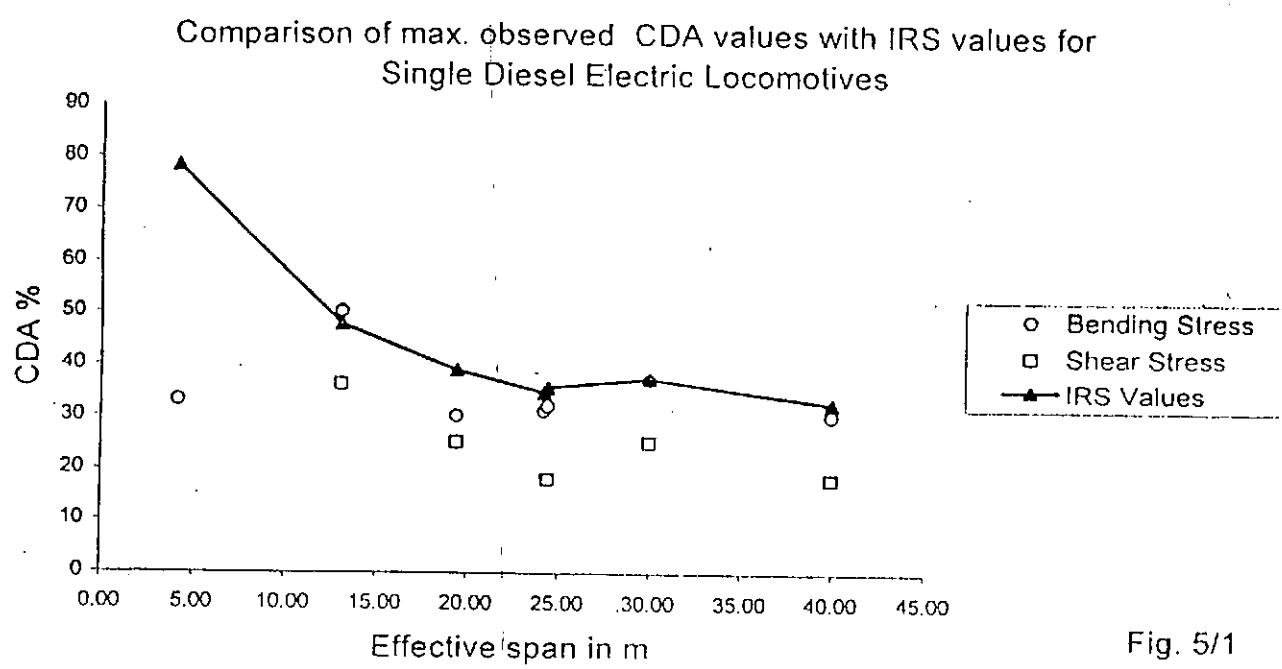

Comparison of max. observed CDA values with IRS values for Single Diesel Electric Locomotives
90
80
70
60
50
40
30
20
10
0
CDA %
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
Effective span in m
Bending Stress
Shear Stress
IRS Values

Fig. 5/1

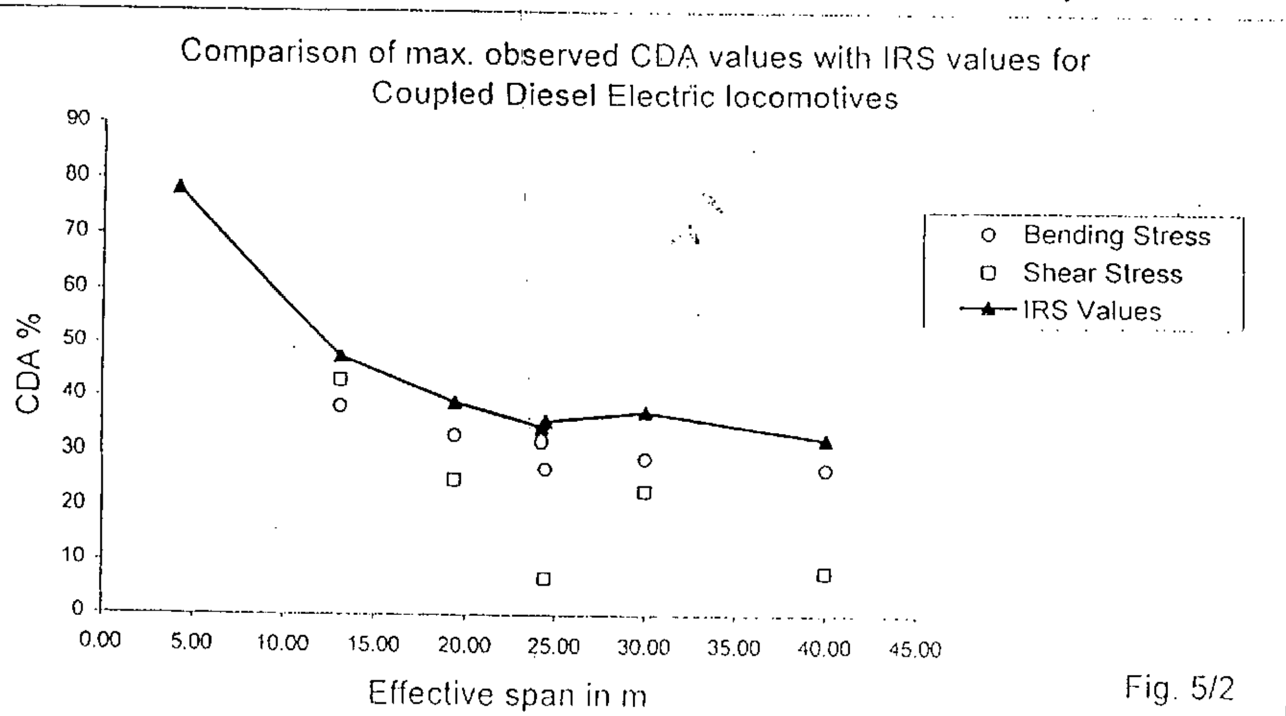

Comparison of max. observed CDA values with IRS values for Coupled Diesel Electric locomotives
90
80
70
60
50
40
30
20
10
0
CDA %
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
Effective span in m
Bending Stress
Shear Stress
IRS Values

Fig. 5/2

Comparison of max. observed CDA values with IRS values for Single Diesel Electric Locomotives + 6 loaded BOXC wagons

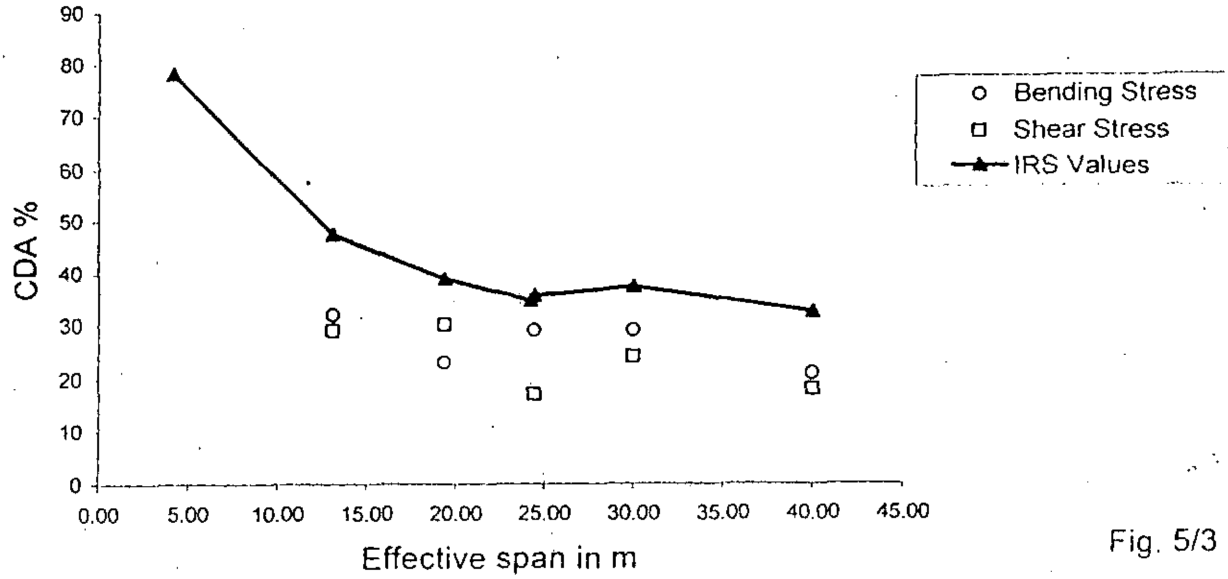


Fig. 5/3

Comparison of max. observed CDA values with IRS values for All Diesel Electric Test train composition.

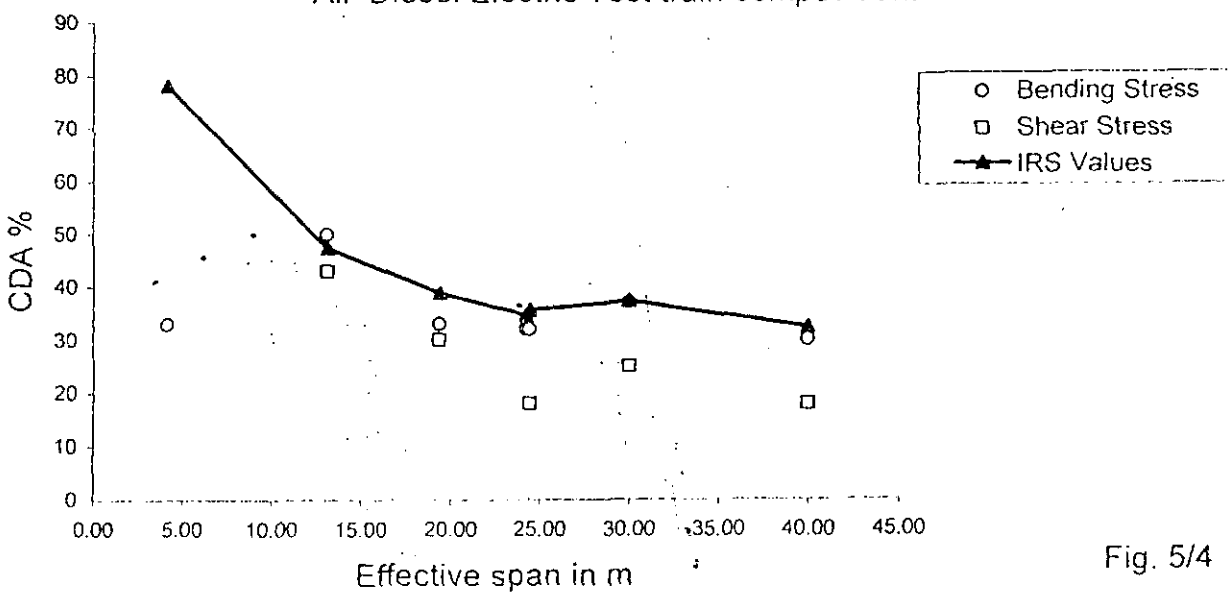


Fig. 5/4

Clause 2.4 of IRS Bridge Rule

2.4 DYNAMIC EFFECT

2.4.1 Railway Bridges (Steel)

2.4.1.1 For Broad and Metre Gauge Railway: The augmentation in load due to dynamic effects should be considered by adding a load equivalent to a coefficient of dynamic augment (CDA) multiplied by the live load giving the maximum stress in the member under consideration. The CDA should be obtained as follows and shall be applicable upto 160 km/h on BG and 100 km/h on MG—

(a) For single track spans :

$$CDA = 0.15 + \frac{8}{(6+L)} \text{ subject to maximum of } 1.0$$

where L is

(1) the loaded length of span in metres for the position of the train giving the maximum stress in the member under consideration.

(2) 1.5 times the cross-girder spacing in the case of stringers (rail bearers) and

(3) 2.5 times the cross girder spacing in the case of cross girders.

(b) For main girders of double track spans with 2 girders CDA as calculated above may be multiplied by a factor of 0.72 and shall be subject to a maximum of 0.72.

(c) For intermediate main girders of multiple track spans, the CDA as calculated in clause 2.4.1.1(a) may be multiplied by a factor of 0.6 and shall be subject to a maximum of 0.6.

(d) For the outside main girders of multiple track spans with intermediate girders, CDA shall be that specified in clause 2.4.1.1(a) or (b) whichever applies.

(e) For cross girders carrying two or more tracks, CDA as calculated in clause 2.4.1.1(a) may be multiplied by a factor of 0.72 and shall be subject to a maximum of 0.72.

(f) Where rails with ordinary fishplated joints are supported directly on transverse steel troughing or steel sleepers, the dynamic augment for calculating stresses in such troughing or sleepers shall be taken as—

$$\frac{7.32}{D+5.49} \text{ for BG}$$

&

$$\frac{5.49}{B+4.27} \text{ for MG}$$

Where D = the spacing of main girders in metres. The same dynamic augmentation (CDA) may be used for calculating the stresses in main girders upto 7.5m effective span, stringers with spans upto 7.5m and also chords of triangulated girders supporting the steel troughing or steel sleepers.

2.4.1.2 For narrow gauge Railways of 762 mm and 610 mm gauges the coefficient of dynamic augment shall be

$$\frac{91.5}{91.5+L}$$

Where,

L is the loaded length of the span as defined in clause 2.4.1.1(a).

2.4.2 Railway pipe culverts, arch bridges, concrete slabs and concrete girders.

2.4.2.1 For all gauges—

(a) If the depth of fill is less than 900 mm, the coefficient of dynamic augment shall be equal to—

$[2-(d/0.9)] \times \frac{1}{2} \times CDA$ as obtained from clause 2.4.1.1(a).

Where, d = depth of fill in 'm'.

(b) If the depth of fill is 900mm the coefficient of dynamic augment shall be half of that specified in clause 2.4.1.1 (a) subject to a maximum of 0.5. Where depth of fill exceeds 900mm, coefficient of dynamic augment shall be uniformly decreased to zero within the next 3 metres.

(c) In case of concrete girders of span of 25m and larger CDA shall be as specified in clause 2.4.1.1.

NOTES : For spans less than 25 m. CDA shall be computed as per sub-clauses(a) or (b) as may be applicable.

(1) The "depth of fill" is the distance from the underside of the sleeper to the crown of an arch or the top of a slab or a pipe.

(2) The above coefficients are applicable to both single and multiple track bridges, subject to Note 3.

(3) On multiple track arch bridges of spans exceeding 15m, 2/3rd of the above coefficient shall be used.

(4) In case of steel girders with ballasted concrete slab decks, coefficient of dynamic augment for the steel spans should be as specified in clause 2.4.1.1.

2.4.3 Foot bridges

No allowance need be made for dynamic effects.

2.4.4 Combined Rail-Road Bridges

For combined rail-road bridges, the allowances for dynamic effects should be in accordance with Clause 2.3.3.

2.4.5 Trestles (Steel), Iron and Concrete

Allowance for dynamic effects shall be as per clauses 2.4.1 to 2.4.4 with appropriate loaded length for the worst possible combination of stresses in the member under consideration.

2.4.6 *Turntable Girders*

All turntable girders shall be designed for a dynamic augment of 10% of the live load with additional allowance, amounting to 100% in all on an axle which is placed at one end of the turntable.

ANNEXURE – II

Specifications of the transducers and recording equipments used on dynamic tests on different concrete bridges.

1.	L.V.D.T. (Linear variable displacement transducer)-	:	Used in measurement of vertical deflection to the centre points of the girders
	Make	:	Electronics Laboratory, RDSO, Lucknow.
	Input Impedance	:	20 ohms
	Output Impedance	:	200 ohms
	Displacement	:	4 cm
	Least count	:	0.01 cm
	Linearity range	:	± 40mm
	Linearity	:	Better than ± 0 .25% of range
	Excitation	:	Voltage 2 to 6 volts. Frequency 500 Hz to 5 KHZ.
	Sensitivity	:	150 micro V/V/mm.
2.(a)	Strain Gauge	:	Used for Bending & Shear strain measurement.
	Make	:	M/s. KYOWA Electronics Instruments Co., Ltd.
	Type	:	KC - A-1-11
		:	KC – 120 A1 – 11, PL-120-11
	Size	:	120mm, 67 mm
	Gauge resistance	:	120 ohm ± 0.3
	Gauge Factor	:	2.11± 1 % 2.13 ± 1%
(b)	Strain gauge	:	Used for measurement of the Loco speed (wheel marker).
	Make	:	M/s. KYOWA ELECTRONICS INSTRUMENT CO. LTD.
		:	M/s. Hytech Micro measurement (P) Ltd.,
	Type	:	KFC 10-C-1-11, AP_2 – 0-530-CX-EL
	Size	:	10mm, 6mm
	Gauge Resistance	:	120.0ohm ± 0.5%
	Gauge Factor	:	2.11 ± 1 %

3. Analog Recording Instrument:-

(a) – I Gould 2600 S (Recorder)

i)	Number of channels	-	6 Nos.
ii)	Channel span	-	50mm
iii)	Trace representation	-	Rectilinear
iv)	Input impedance	-	100 K Ohm ± 1%
v)	Input signal	-	5 Volt span
vi)	Power consumption	-	360watts
vii)	Chart speed	-	5, 10, 25, 50, 100, 200 mm/sec and divided by 100.

(a) - II Carrier Amplifier used with above recorder:

i)	Input Impedance	-	1 M Ohm.
ii)	Transducers excitation	-	Internal adjustment from 2 volt to 10V RMS
iii)	Frequency	-	2500 Hz + 5% sinewave
iv)	Output voltage	-	0-5V DC
v)	Power requirement	-	230 V AC 50 Hz
vi)	Warm up time	-	15 minutes
vii)	Operating temperature	-	- 40 ^{0}C to 70^0 C
viii)	Auto Balance	-	Front panel switch with indicator

(b) – I Gould 260 Recorder:

i)	No. of channel	-	6 Nos,
ii)	Channel Spans	-	40mm (5 Div.)
iii)	Trace representation	-	Rectilinear
iv)	Impedance	-	30 K Ohms
v)	Input signal	-	5 V Span
vi)	Sensitivity	-	1m V/Div.
vii)	Chart Speed	-	5,10,25,50,100,200 and divided by 100

(b) - II Carrier Amplifier used with the above Recorder

i)	Input Impedance	-	30 K Ohms constant
ii)	Excitation Voltage	-	5 Volt RMS
iii)	Frequency	-	2 K Hz $\pm$ 5%
iv)	Level	-	$\pm$ 2.5 VDC into 50 K Ohms
v)	Power requirement	-	230 V AC 50 Hz
vi)	Warm up time	-	15 minutes
vii)	Operating temperature	-	0 ^{0}C to 55^0 C

4. ASTRO MED MT – 9500 Recorder:

i) It can display (Simultaneously) 8 wave forms.
ii) 9 event on/off channel.
iii) It has complex interfacing with a 32 bit computer bus.

iv)	Power requirement	:	240 v (190 to 264 v) 48 Hz to 440 Hz
iv)	Recording method	:	Direct writing thermal array.
v)	Resolution	:	20 dots/inch across paper width.
vi)	Channel grid format	:	80 No 40 mm or 3 Nos 60 mm.
vii)	Frequency range	:	DC to 3 KHz down 1 db DC to 5 KHz down 3 db.
vii)	A.D. resolution	:	12 bit

ANNEXURE -III

Calibration Details

The calibration of oscillograph traces for determining strains was done using high shunt resistance 240 k ohm and 270 k ohm across one of the active arms of the wheat stone bridge.

The following formula was used to obtain strain for the shunt resistance:

$$\text{Strain} = RG / (RG+RS) \times 1/GF$$

Where,

RG	=	Resistance of the strain gauge used in active arms in ohms.
RS	=	Shunt resistance used in ohms.
GF	=	Gauge factor.

2. The strain as obtained above divided by the corresponding ordinate (div) of the trace deviation due to application of shunt resistance gives the calibration factor for a particular measuring channel.

3. Calibration of oscillograph for deflections as measured by LVDT was done by inserting a standard feeler gauge of 5 mm thick in between the spindle of the LVDT and the bottom of bottom slab of PSC Box girder. Feeler gauge thickness (mm) divided by trace deviation in division gives the calibration factor for LVDT channel.