"Multi support excitation of steel I girder bridge under Spatially Varied Earthquake Ground Motion"

A Thesis

Submitted in Partial Fulfillment of the Requirement for the Award of the Degree of

Master of Technology

In

CIVIL ENGINEERING

With specialization in

Structural Engineering

Under the supervision of

Mr. Bibhas Paul

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DECLARATION

I hereby declare that the work reported in the M.Tech thesis entitled "**Multi support excitation of steel I girder bridge under Spatially Varied Earthquake Ground Motion"** submitted at **Jaypee University of Information Technology, Waknaghat, Solan(H.P)** is an authentic record of my work carried out under the supervision of **Mr. Bibhas Paul.** I have not submitted this work elsewhere for any other degree or diploma.

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CERTIFICATE

This is to certify that the work which is being presented in the thesis titled **"Multi support excitation of steel I girder bridge under Spatially Varied Earthquake Ground Motion"** in partial fulfillment of the requirements for the award of the degree of Master of Technology in Civil Engineering with specialization in "**Structural Engineering**" and submitted to the Department of Civil Engineering, Jaypee University Information Technology, Waknaghat is an authentic record of work carried out by Smriti Sharma (152662) during a period from July 2016 to May 2017 under the supervision of **Mr. Bibhas Paul** Assistant Professor, Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of our knowledge.

Date: - ………………………

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Professor & Head of Department	Assistant Professor	
Department of Civil Engineering	Department of Civil Engineering	
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Finally, I am very much thankful to God for the shower of warm blessings and my parents, my sisters and my brother for their moral support and continuous encouragement while carrying out this study.

Smriti Sharma

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Abstract

Response of steel I girder bridge subjected to spatially varied ground motions is examined through response spectrum and time history analysis. It is easy to predict or calculate the response of small base structures like buildings under spatially varied ground motions because the excitations caused by earthquake is considered to be same at all supports . But for extended areas like long span bridge structure is one of challenge for engineers to investigate the response and dynamic behavior under the effect of spatially varied ground motions The spatially varied ground motions implemented in the structure are due to three causes; a) wave passage effect i.e. difference in arrival of wave or time lag effect at different supports .b) loss of coherency i.e. difference in amplitudes of waves due to different medium of ground c) local site conditions i.e. the type of soil (soft, firm, hard).

Simulation of ground motions with different efficient algorithms and computer code (using MATLAB) were generated in the form of time period and acceleration. Kanai –Tajimi model is used for simulation of ground time history analysis. Using actual earthquake record data with different magnitude and frequencies for evaluating the model for time history analysis is done. Moments and shear force for different loading, response spectrum and time history analysis for different ground motions is calculated. It is concluded that the moments and shear force considering wave passage effect, loss of coherency and local site conditions are much higher than others.

Chapter 1: Introduction

1.1General

Analysis of two span continuous steel I girder bridge, with overall span length of 120m (60m each) and vehicles moving across is performed .It is easy to predict or calculate the response of small base structures like buildings under spatially varied ground motions because the excitations caused by earthquake is considered to be same at all supports . But for extended areas like long span bridge structure is one of challenge for engineers to investigate the response and dynamic behavior under the effect of spatially varied ground motions. The spatially varied ground motions implemented in the structure are due to three causes; a) wave passage effect i.e. difference in arrival of wave or time lag effect at different supports .b) loss of coherency i.e. difference in amplitudes of waves due to different medium of ground c) local site conditions i.e. the type of soil (soft, firm, hard).

From last 30 years, different methodology, techniques and tools were used by different engineers and researchers for examine the behavior of structure by different analysis like: time history analyses, responses spectrum analysis and random vibration approach.

Der kiureghian and Neuenhofer(1992) had firstly developed the multi support response spectrum for analysis of bridge structure which is now using by different researchers.

The equation of motion in which variation of loading w.r.t. time is completely known is given by:

$$m\ddot{x} + c\dot{x} + kx = f(t) \qquad (1)$$

Where, m is inertial force i.e. movement of mass under dynamic force.

$$f(I) = m\ddot{x}\ \text{(t)}$$

c is damping force i.e. dissipation of energy.

$$f(D) = c\dot{x}\ (t)$$

k is restoring force/ stiffness causing elasticity in the system called spring force.

$$f(S) = kx\ (t)$$

Suppose forces(x,y,z,t) subjected to structure(k,m,c) response will be u(x,y,z,t).

To generate the artificial accelerograms for input excitations using Kanai Tazimi model with different algorithms and computer code was used.

1.2 Objective

1 To predict the response of long span bridge accurately with

- Wave passage
- Incoherence effect
- Local site conditions.

1 To generate spatially varied earthquake ground motion (SVEGM) using Kanai Tazimi model for Simulation.

2 Analysis with time history analysis

In this study, we analyzed the dynamic behavior of steel I girder bridge and develop the spatially varied ground motions subjected to wave passage, incoherence effect and local site conditions. An accurate tools for analysis of steel I girder bridge was done using response spectrum and time history analysis.

Chapter 2: Literature Review

2.1 General

Shinozuka(1972)[1], represented the simulation of ground motions in the form of computer based work as gaussian random process with some trigonometric functions.

Yang(1972)[2],introduced the Fast Fourier Transform(FFT) technique to reduce the Shinozuka computational time for simulation of ground motions. Later on Shinozuka (1987)[3] had used his FFT technique for analysis. Zerva(1992)[4] used Shinozuka's method with FFT for analysis.

Ahmed M. Abdel-Ghaffar and Richard G. Stringfelow(1984**)**5 analysed response of suspension bridge with random vibration technique. The actual earthquake ground motions were taken in the form of frequency and implementation of different seismic speeds at supports was done Vibration displacements, stresses, shear force were calculated and compared at critical section og a bridge.

Hrichandran and Vanmark(1986)[6], studied the reversion of earthquake in SMART-1-array. They investigated the response of simply supported beam and considered ground motions as random process. They obtained spectral density equations for analysis in multi support excitations.

Nazmy and Abdel Ghaffar (1992)[7], analyzed the dynamic behavior of cable stayed bridge with different artificial accelerograms as input ground motions at different piers supports of bridge.

Der-Kiurenghian and Neuenhofer(1992)[8]developed multi Support response spectrum to different support excitations. In this metod he included the input excitations by three main causes i.e. wave passage effect, incoherence effect and local site conditions.

Ronald S. Harichandran, Ahmad Hawwari and Basheer N. Sweida (1996)[9], presented the results of stationary and transient force on different bridges corresponding to spatially varied ground motions. The kanai tajimi model was used and computer based identical and delayed excitations

were generated as input excitations. They concluded that results from the effects of spatially varied ground motions of stationary and transient force were approximately same.

Kahan et –al (1996)[10] extended the analysis of spectral density carried by Der-Kiurenghian and Neuenhofer and studied the reciprocation of bridges at different supports.

Jianhua Li1, Jie Li2(2004)[11], analysed response spectrum on two span beam like structure under multi support excitations. A white noise procedure was demonstrated and computer based results were concluded. These results were compared with Monte Carlo simulation and MSRS and concluded that computer based algorithms is a better result for analysis.

H.Ghaffarzadeh and M.M Iradi(2008)[12]. Developed an AAN (Arterial Neural Network) for simulation of artificial earthquake excitations and analysis is done with response spectrum analysis.

Chapter 3: Bridge Model in CSi Bridge

3.1General

CSi is an structural and earthquake building programming organization established in 1975 and situated in Walnut River, California with extra office area in New York The basic analysis and design programming CSI deliver incorporate SAP2000, CSi Bridge, ETABS, SAFE, PERFORM-3D, and CSi COL. CSI-Bridge 2016v1811 as the name suggests is worked for the structural analysis and outline of bridges of different sorts (Prestressed I-Girder, Box Girder, Steel Girder, Curve).

CSiBridge is specific examination and plan programming custom fitted for the designing of extension frameworks. It account for dynamic effects, inelastic behavior, and geometric nonlinearity. Code-based templates streamline the engineering process from model definition through analysis, design optimization, and the generation of comprehensive output reports. CSiBridge is the premier software for bridge engineering.

CSiBridge executes a parametric protest based demonstrating approach when creating explanatory scaffold frameworks. This enables designers to assign bridge composition as an assembly of objects. Analysis Engine, integral to CSI Software, automatically transfers the object-based model into a mathematical finite-element model by meshing the material domain and assigning material properties. This object-oriented approach simplifies and expedites the modeling process, saving engineers the need to directly define, link, constrain, and mesh all material volumes.

CSiBridge likewise enables architects to import display information from Dwg/Dxf, IGES, CIS/2 Stage, and Land XML document arrangements, or fare to PERFORM-3D, MS Get to, and CIS/2 Stage, all after IFC models.

In the wake of displaying, CSiBridge gives choices to the task of load cases and mixes. Vehicle, seismic, and wind stacking are created by construction regulation (AASHTO LRFD, Canadian, and so on.) and doled out as per model geometry.

3.2 Dimensions Detail of Composite steel I girder:

Bridge Layout:

- No. of spans-2
- Span length- 60m, 60m
- Total Length-120m
- No. of lanes-2

Bridge Layout Line	Station (m)	Centerline Offset Line (m)	Lane Width(m)
BLL1	0	1.8	3.67
BLL1	120	1.8	3.67
BLL2	0	-1.8	3.67
BLL2	120	-1.8	3.67

Bridge Components:

- Material Properties- Fe345, M40
- Frame properties

1. Steel I girder-

Total No. of girders	4, 2(interior),2(exterior)
Outside Height(t3)	2.24m
Top flange width(t2)	0.5m
Bottom flange width(t2b)	0.5m
Top flange thickness(tf)	0.02m
Bottom flange thickness(tfb)	0.02m
Web thickness(tw)	0.025m
Material Property	Fe345

2. Abutment-

Type	Concrete(Rectangular)
Depth(t3)	2.44m
Width(t2)	1.22m
Material property	M40

3. Bent-

No. of bents	3
Type	Circular concrete column
Diameter	1.52m
Spacing	0.762,4.575,8.3875m
Height	8m
Material Property	M40

4. Bent Cap-

Type	Concrete (rectangular)
Depth(t3)	3.05m
Width(t2)	1.52m
Material Property	M40

- Items-

1. Deck section-

Slab Material Property	M40
No. of interior girders	2
Total Width	10.98m
Girder longitudinal layout	Along layout line
Constant girder spacing	Yes
Total slab thickness(t1)	0.305m
Concrete haunch+ steel flange thickness(t2)	0.075m
Girder modeling object type	Mixed
Girder section	Steel girder
Maximum meshed element height for girder web	0.3048m

2. Diaphragm-

   Single beam (applies to steel bridges only)

   Beam section property – Steel Girder

3. Bearings-

Direction	Release type
Translation vertical(U1)	Fixed
Translation normal to layout line(U2)	Fixed
Translation along layout line(U3)	Free
Rotation about vertical (R1)	Free
Rotation about normal to layout line(R2)	Free
Rotation along layout line(R3)	Free

4. Foundation Spring-

Direction	Release type
Translation vertical(U1)	Fixed
Translation along skew(U2)	Fixed
Translation normal to skew(U3)	Fixed
Rotation about vertical(R1)	Fixed
Rotation about line along skew(R2)	Fixed
Rotation about line normal to skew(R3)	Fixed

5. Loads patterns –

- Dead load(self weight)
- Live load (vehicle live)(70R Loading)
- Seismic load(quake)

6. Bridge object name –

- Define Bridge Spans

Span label	Start Station(m)	Length(m)	End Station (m)	Start Support	End Support
Span 1	0	60	60	Abutment	Bent
Span2	60	60	120	Bent	Abutment

- In Span cross diaphragm definition

Span	Distance (m)	Ref line
Span1	10	Layout Line
Span1	20	Layout Line
Span1	30	Layout Line
Span1	40	Layout Line
Span1	50	Layout Line
Span2	10	Layout Line
Span2	20	Layout Line
Span2	30	Layout Line
Span2	40	Layout Line
Span2	50	Layout Line

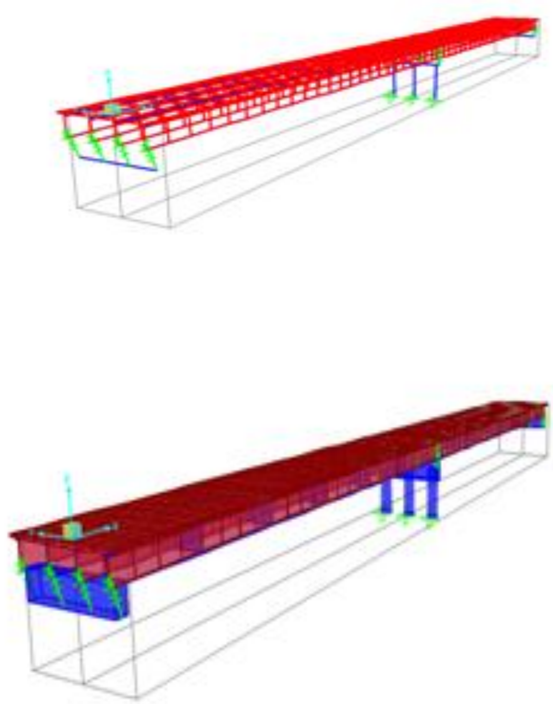


Figure 1: Model of steel I girder Bridge

Chapter 4: Multi support excitation and ground motion simulation

4.1General

It is very important to perform the dynamic analysis subjected to dynamic loadings i.e. time history and response spectrum analysis. The equation of motion for dynamic equilibrium subjected to earthquake ground motions in terms of mass[M],damping[C] and stiffness[K] is:

$$\begin{bmatrix} M_{ii} & M_{is} \\ M_{si} & M_{ss} \end{bmatrix} \begin{Bmatrix} \ddot{X}_i \\ \ddot{X}_s \end{Bmatrix} + \begin{bmatrix} C_{ii} & C_{is} \\ C_{si} & C_{ss} \end{bmatrix} \begin{Bmatrix} \dot{X}_i \\ \dot{X}_s \end{Bmatrix} + \begin{bmatrix} K_{ii} & K_{is} \\ K_{si} & K_{ss} \end{bmatrix} \begin{Bmatrix} X_i \\ X_s \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \end{Bmatrix} \tag{2}$$

Where $\{\ddot{X}_i\}, \{\dot{X}_i\}\ and \{X_i\}$ are the absolute acceleration, velocity and displacement of interior DOF and $\{\ddot{X}_s\}, \{\dot{X}_s\} and \{X_s\}$ are the absolute acceleration, velocity and displacement vectors corresponding to support DOF.

4.1.1Relative motion method (RMM)

It is based on principle of superposition. Total response of structure by this method is given by:

$$\begin{Bmatrix} X_i \\ X_s \end{Bmatrix} = \begin{Bmatrix} X_i^d \\ 0 \end{Bmatrix} + \begin{Bmatrix} X_i^s \\ X_s \end{Bmatrix} \tag{3}$$

Where $\{X_i^d\}, \{X_s\}\ and\ \{X_i^s\}$ is relative response of interior DOF, absolute earthquake ground displacement at supports and pseudo static response respectively.

a) Pseudo static response component:

$$\begin{bmatrix} K_{ii} & K_{is} \\ K_{si} & K_{ss} \end{bmatrix} \begin{Bmatrix} X_i^s \\ X_s \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \end{Bmatrix} \tag{4}$$

Where $\{X_I^S\}$=$[R]\{X_s\}$

[R] is a matrix of influence coefficients obtained from solution of $[K_{ii}][R]= -[K_{is}]$

b) Dynamic response component

$$[M_{ii}]\{\ddot{X}_i^d\} + [C_{ii}]\{\dot{X}_i^d\} + [K_{ii}]\{X_i^d\} = -([M_{ii}][R] + [M_{is}])\{\ddot{X}_S\} \tag{5}$$

Once the pseudo static and dynamic displacements response components obtained, the earthquake induced internal forces are computed from superposition of dynamic and pseudo static internal forces.

4.1.2 Large mass method (LMM)

It is a penalty method in which specified accelerograms, the inertia forces are developed at support and considered as external driving force, thus equation (2) can be written as:

$$\begin{bmatrix} M_{ii} & M_{is} \\ M_{si} & \left(M_{ss}+M_{ii}\right) \end{bmatrix} \begin{Bmatrix} \ddot{X}_i \\ \ddot{X}_s \end{Bmatrix} + \begin{bmatrix} C_{ii} & C_{is} \\ C_{si} & C_{ss} \end{bmatrix} \begin{Bmatrix} \dot{X}_i \\ \dot{X}_s \end{Bmatrix} + \begin{bmatrix} K_{ii} & K_{is} \\ K_{si} & K_{ss} \end{bmatrix} \begin{Bmatrix} X_i \\ X_s \end{Bmatrix} = \begin{bmatrix} 0 \\ (M_{ss}+M_{ii}) \end{bmatrix} \left\{\ddot{X}_s\right\} \tag{6}$$

Since $\{\ddot{X}_s\}$ is arbitrary, multi support excitation can be modeled by this method. The earthquake induced internal forces will be obtained directly.

4.2 Ground Motion Simulation

Using kanai Tajimi model in MATLAB, ground motions were generated for different frequencies and time. Time history analyses were done for calculating response of entire bridge in the form of moment and shear force. Based on Kanai's investigation regarding the frequency content of different earthquake records, Tajimi proposed the following relation for the spectral density function of the strong ground motion with a distinct dominant frequency:

$$G(\omega) = \frac{\left[1+4\xi_g^2(\omega/\omega_g)^2\right]}{\left[1-(\omega-\omega_g)^2+4\xi_g^2(\frac{\omega}{\omega_g})^2\right]} \mathrm{G_O} \tag{7}$$

Here, (γ_g)and(ω_g) are the site dominant damping coefficient and frequency, and G_0 is the constant power spectral intensity of the bed rock excitation. In practice these parameters need to be estimated from the local earthquake records and/or site geological features. The Kanai–Tajimi power spectral density function may be interpreted as corresponding to an 'ideal white noise' excitation at the bedrock level filtered through the overlaying soil deposits at a site. The most serious shortcoming of the original Kanai–Tajimi model is its treatment of earthquakes as stationary random processes. An improved version of the model was introduced capture the nonstationary feature of the real earthquake records. (See annexure 1)

5.1 Calculation of moments and shear forces after analyses:

5.1.1 Considering dead load

a) For entire bridge

Layout Line Distance	M3
m	KN-m
0	-1.53E-06
20	27404.9715
30	24750.126
40	11190.3929
50	-13274.2278
60	-48643.736
70	-13274.2278
80	11190.3929
90	24750.126
100	27404.9715
110	19154.9295
120	-1.53E-06

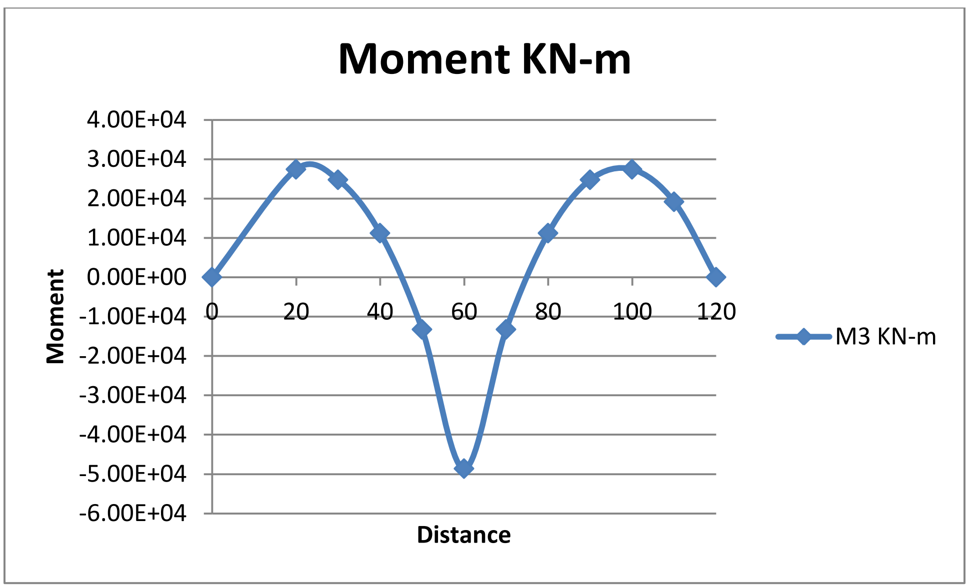


Figure 2: Moment of entire bridge for D.L

Layout Line Distance	V2
m	KN
0	-2434.326
20	-306.171
30	784.318
40	1874.806
50	3018.118
60	-4055.784
70	-2965.295
80	-1927.629
90	-784.318
100	253.349
110	1343.837
120	2434.326

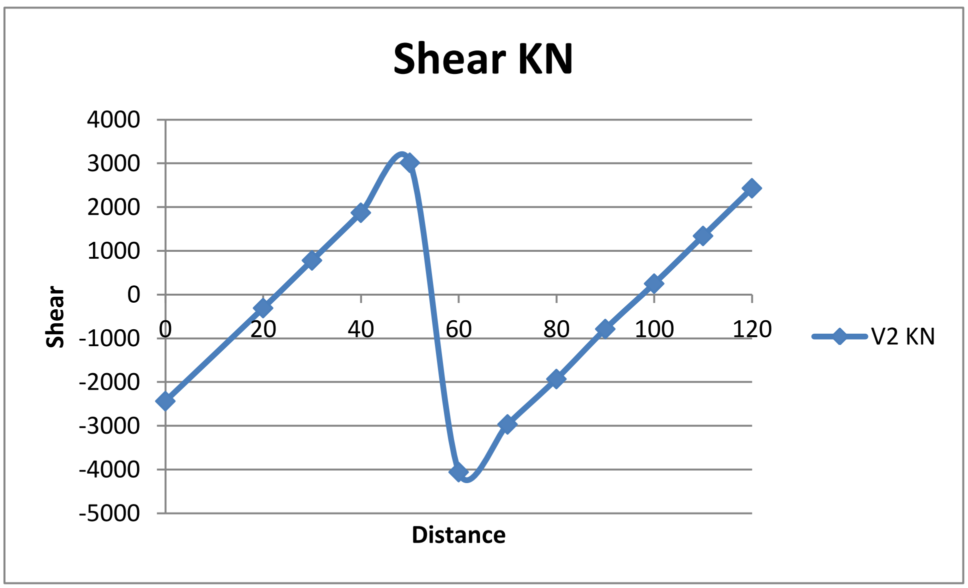


Figure 3: Shear force of entire bridge for D.L.

b) Left exterior girder

Layout Line Distance	**M3**
m	KN-m
0	-0.7945
10	4638.8573
20	6647.9379
30	6012.9025
40	2741.1226
50	-3216.6487
60	-11675.638
70	-3193.5871
80	2741.1226
90	6012.9025
100	6647.9379
110	4638.8573
120	-0.7945

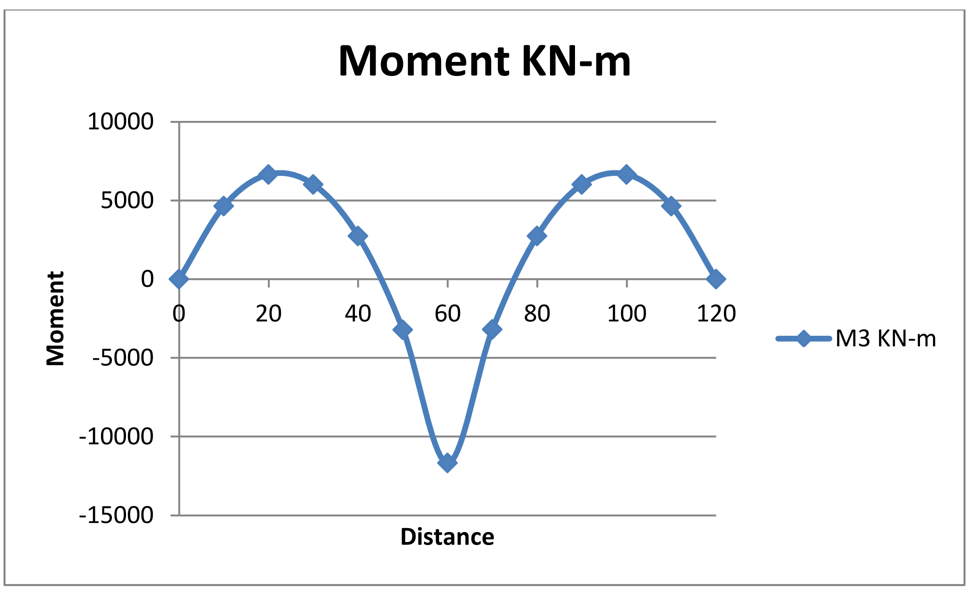


Figure 4: Moment of left exterior girder for D.L.

Layout Line Distance	V2
m	KN
0	-589.673
10	-323.248
20	-49.523
30	224.63
40	501.562
50	725.33
60	964.57
70	-758.333
80	-501.562
90	-224.63
100	49.523
110	323.248
120	589.673

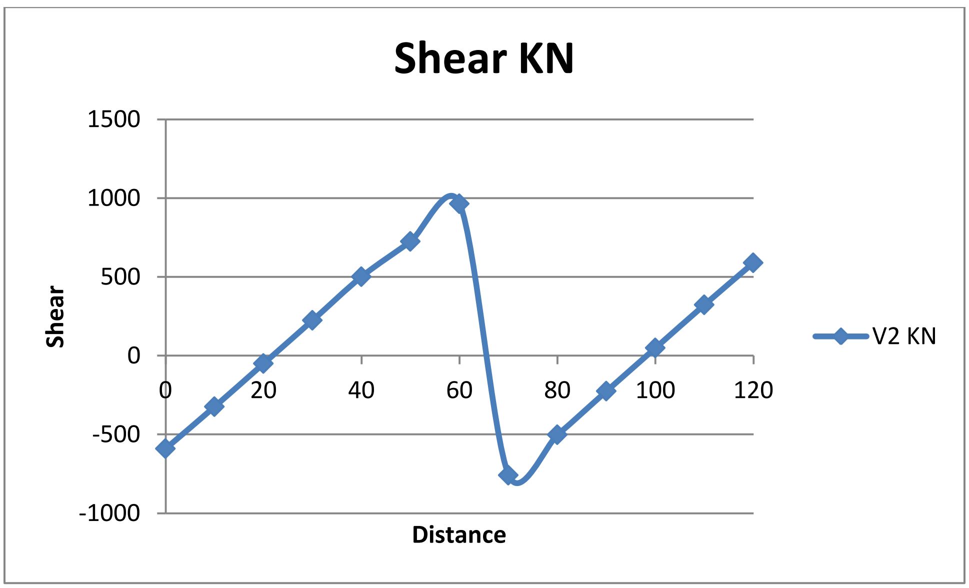


Figure 5: Shear force of left exterior girder for D.L.

c) Interior girder 1

Layout Line Distance	M3
M	KN-m
10	4925.5754
20	7051.9334
30	6369.0649
40	2870.479
50	-3443.5267
60	-12646.2299
70	-3443.5267
80	2854.0739
90	6362.1605
100	7051.9334
110	4925.5754
120	0.7945

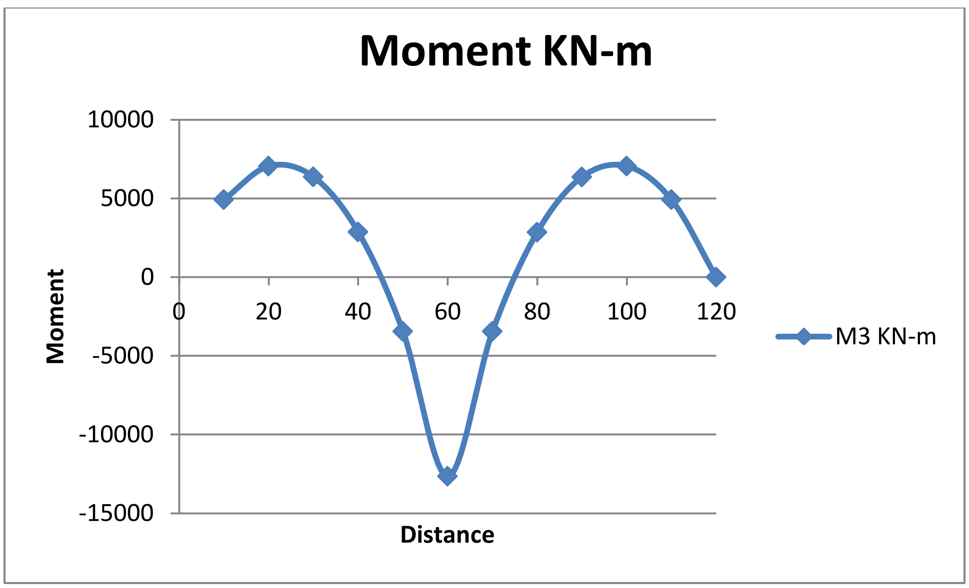


Figure 6: Moment of interior girder1 for D.L.

Layout Line Distance	V2
m	KN
10	-333.011
20	-60.479
30	210.534
40	483.909
50	750.725
60	-1063.322
70	-750.725
80	-462.253
90	-193.94
100	60.479
110	333.011
120	627.49

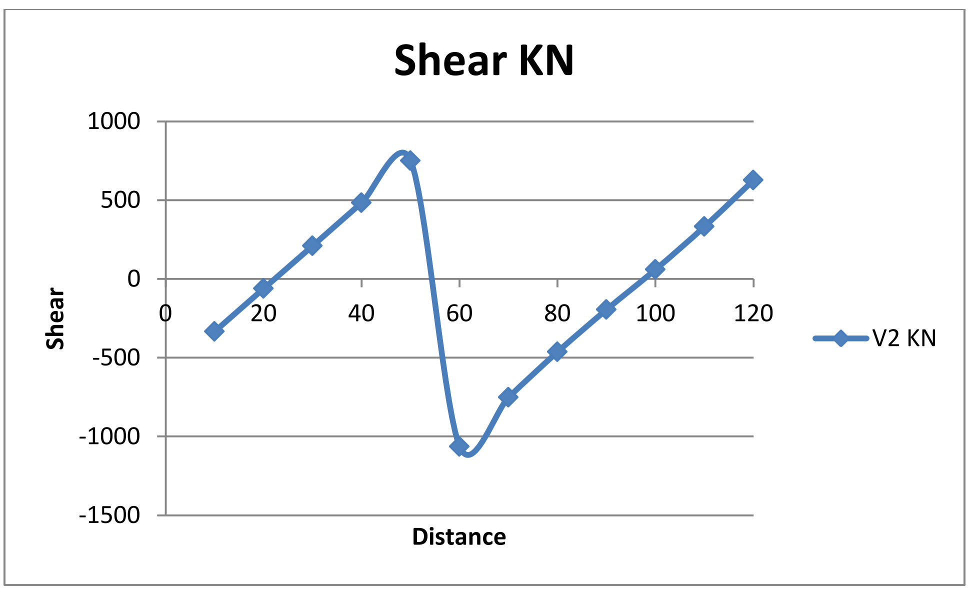


Figure 7: Shear force of interior girder 1 for D.L.

d) interior girder 2

Layout Line Distance	M3
m	KN-m
10	4938.6075
20	7054.5479
30	6362.1605
40	2854.0739
50	-3420.4652
60	-12646.2299
70	-3443.5268
80	2854.0739
90	6369.0649
100	7051.9334
110	4925.5754
120	0.7945

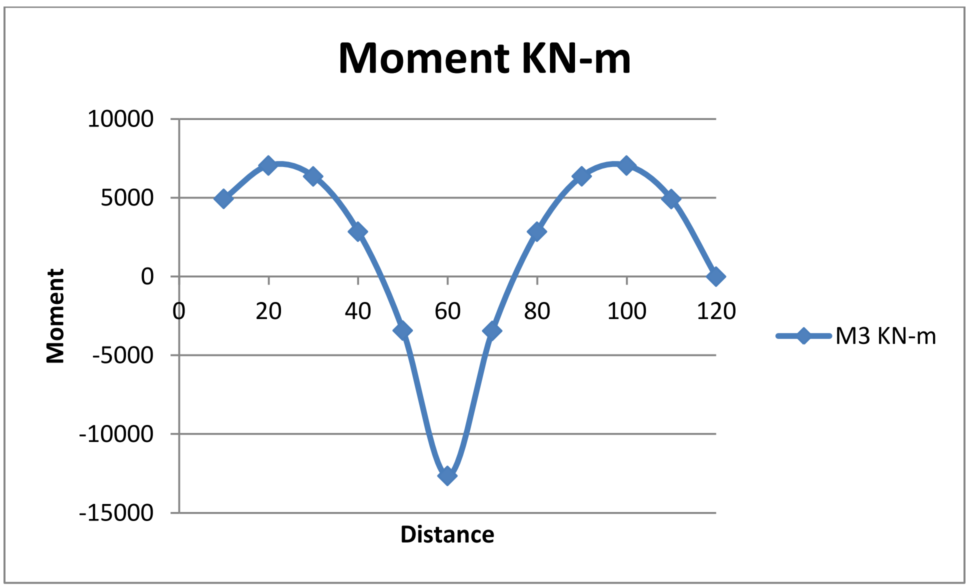


Figure 8: Moment of interior girder 2 for D.L.

Layout Line Distance	V2
m	KN
10	-348.671
20	-77.151
30	193.94
40	462.253
50	757.317
60	1063.322
70	-750.725
80	-462.253
90	-210.534
100	60.479
110	333.011
120	627.49

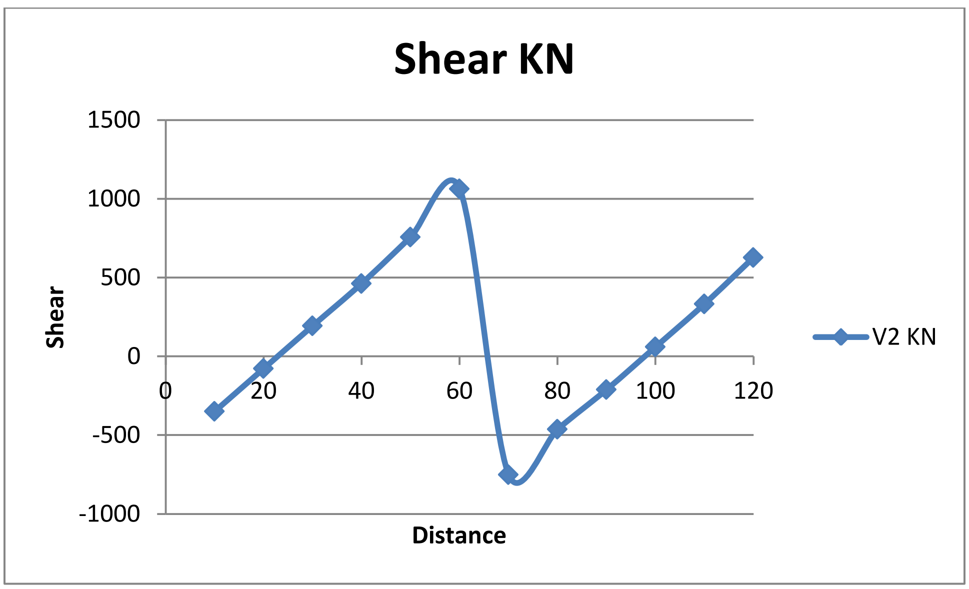


Figure 9: Shear force of interior girder2 for D.L.

e) Right exterior girder

Layout Line Distance	M3
m	KN-m
0	-0.7945
10	4638.8573
20	6647.9379
30	6005.9981
40	2724.7174
50	-3193.5872
60	-11675.6381
70	-3193.5872
80	2741.1226
90	6005.9981
100	6650.5524
110	4638.8573
120	-0.7945

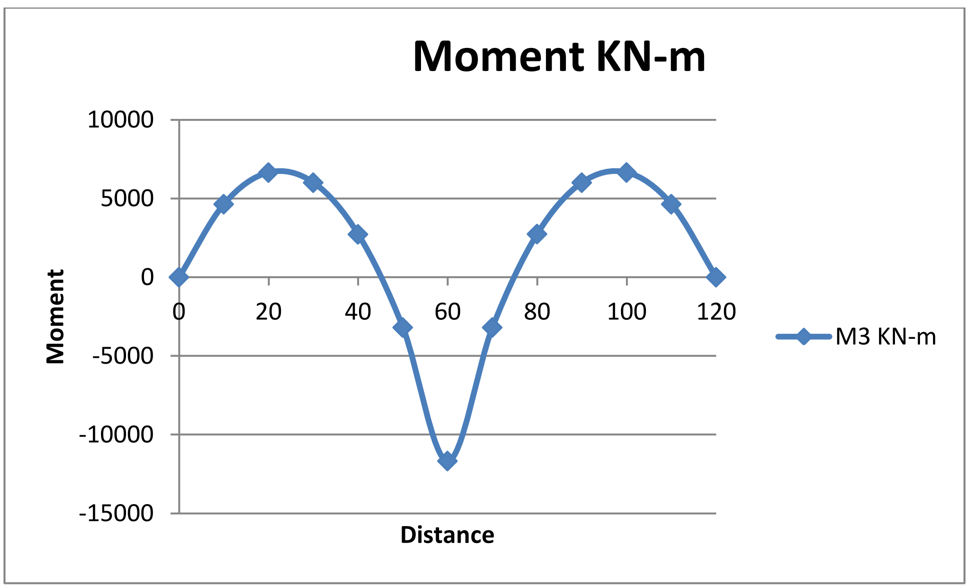


Figure 10: Moment of right exterior girder for D.L.

Layout Line Distance	V2
m	KN
0	-589.673
10	-323.248
20	-49.523
30	181.624
40	453.494
50	758.333
60	964.57
70	-758.333
80	-501.562
90	-181.624
100	92.607
110	323.248
120	589.673

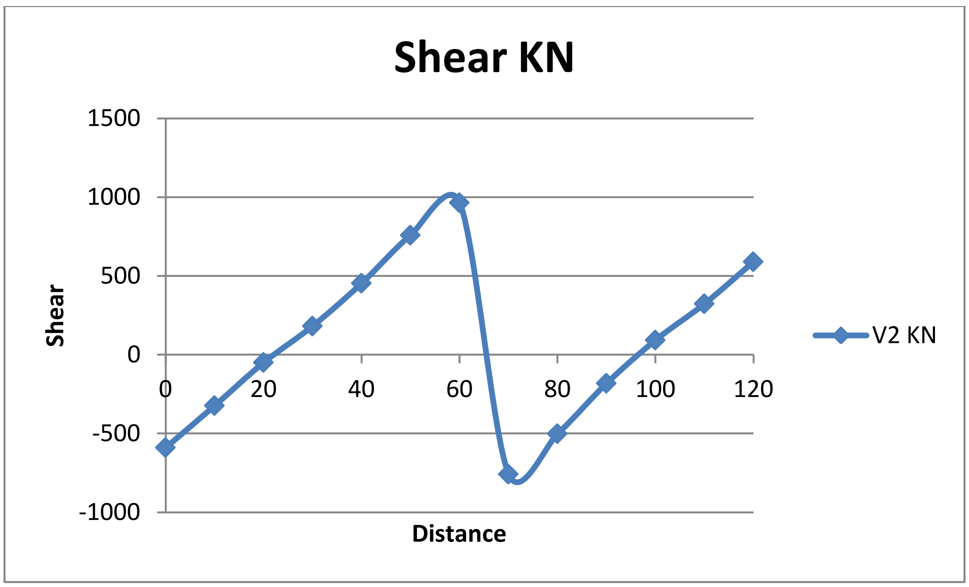


Figure 11: Shear force of right exterior girder for D.L.

5.1.2 .Considering live load

a) For entire bridge

Layout Line Distance	M3
m	KN-m
0	0
10	6076.1176
20	8648.2222
30	7607.1023
40	4457.4417
50	752.9119
60	0
70	752.9119
80	4457.4417
90	7607.1023
100	8648.2222
110	6076.1176
120	1.04E-09

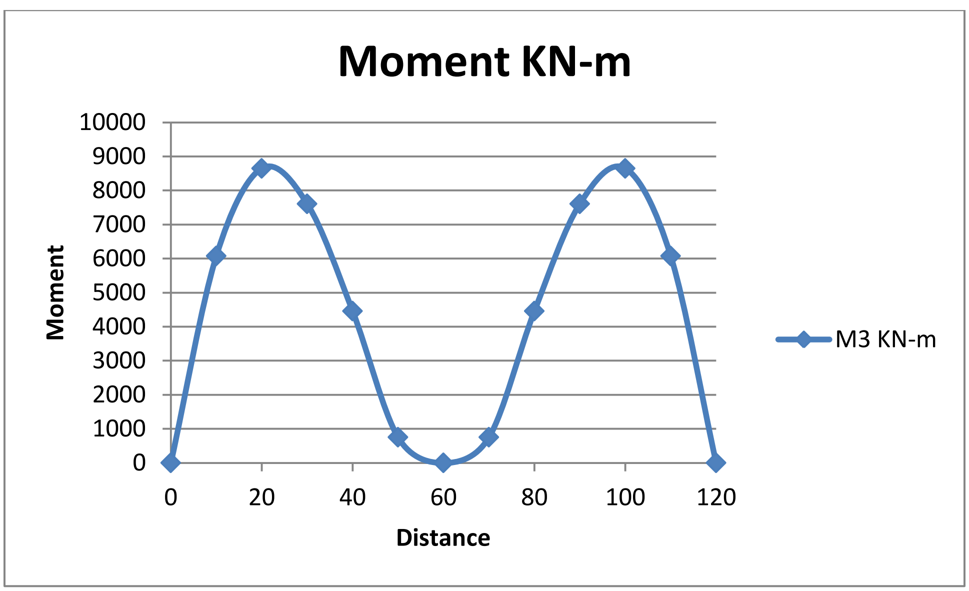


Figure 12: Moment of entire bridge for L.L.

Layout Line Distance	V2
m	KN
0	0.015
10	74.781
20	294.522
30	475.023
40	710.142
50	835.773
60	937.813
70	8.713
80	42.852
90	154.823
100	353.709
110	559.86
120	745.899

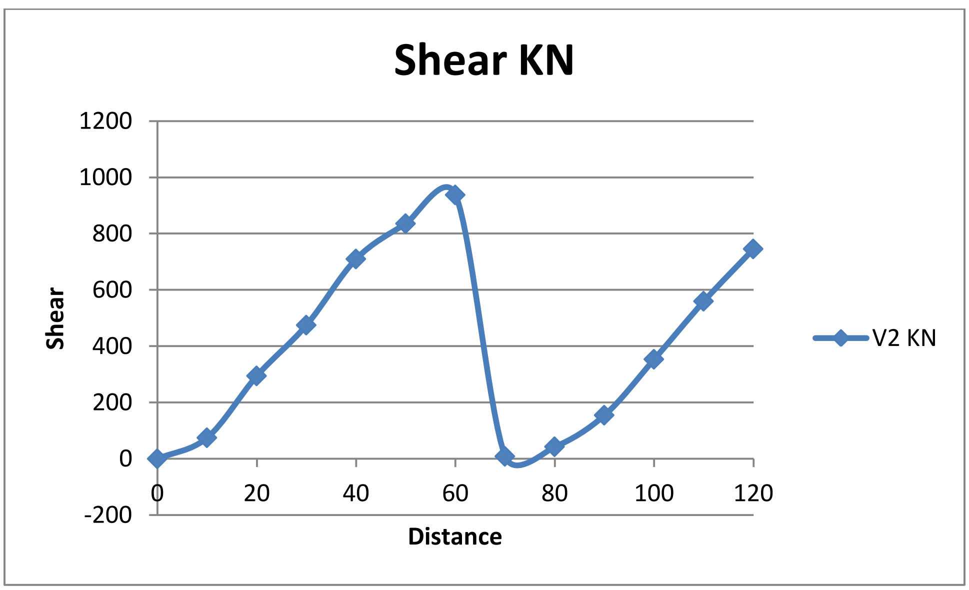


Figure 13: Shear force of entire bridge for L.L.

b) Left exterior girder

Layout Line Distance	M3
m	KN-m
0	0.2646
10	2561.9757
20	3711.4762
30	3514.5491
40	2680.092
50	1190.3292
60	0
70	1129.4291
80	2692.216
90	3569.6155
100	3700.6467
110	2552.4941
120	0.5559

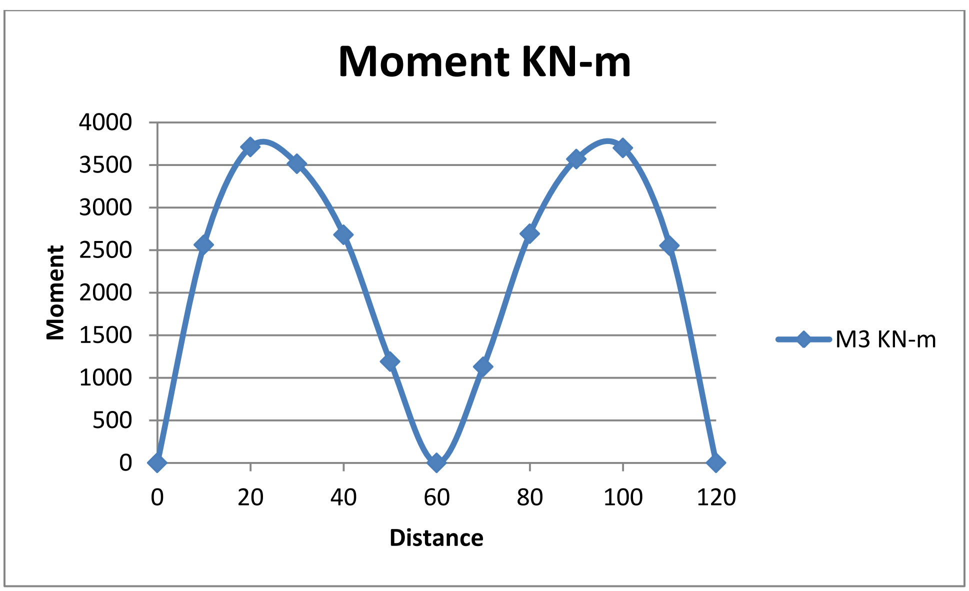


Figure 14: Moment of left exterior girder for L.L.

Layout Line Distance	V2
m	KN
0	7.188
10	36.494
20	58.05
30	133.205
40	205.792
50	328.002
60	3.15E-03
70	3.08E-03
80	15.62
90	60.711
100	117.068
110	185.166
120	279.393

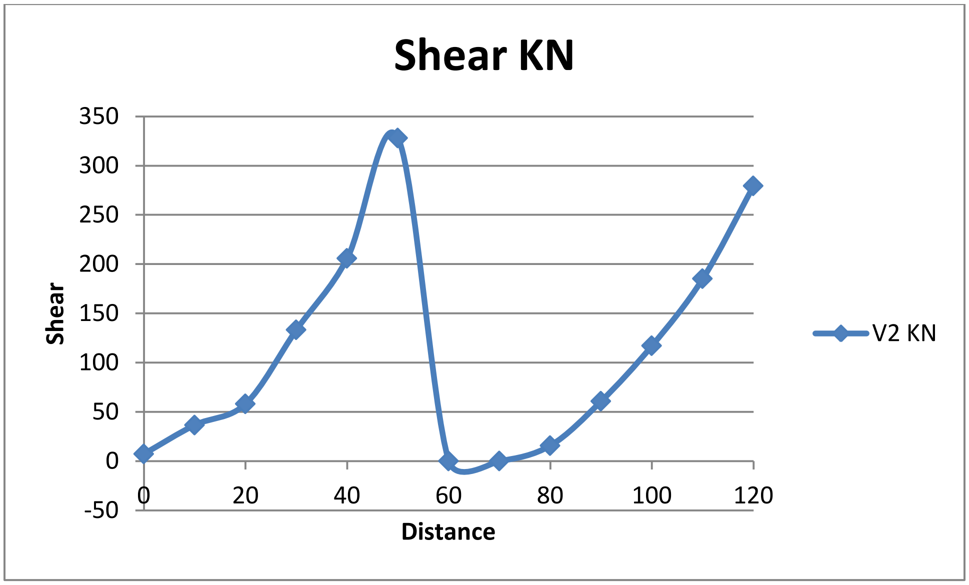


Figure 15: Shear force of left exterior girder for L.L.

c) Interior girder 1

Layout Line Distance	M3
m	KN-m
0	0.7257
10	1827.1511
20	2668.9914
30	2441.7197
40	1546.9595
50	409.4375
60	0
70	374.3028
80	1579.9892
90	2424.1286
100	2635.0121
110	1837.4636
120	0.8529

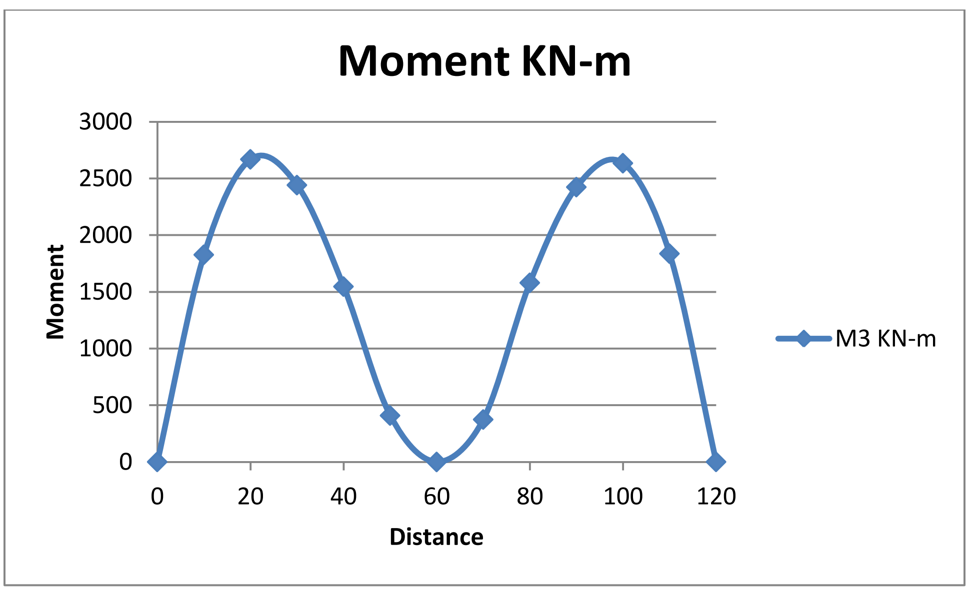


Figure 16: Moment of interior girder1 for L.L.

Layout Line Distance	V2
m	KN
0	0
10	14.806
20	90.391
30	125.028
40	189.28
50	395.887
60	351.139
70	107.86
80	178.533
90	44.777
100	231.815
110	324.866
120	281.622

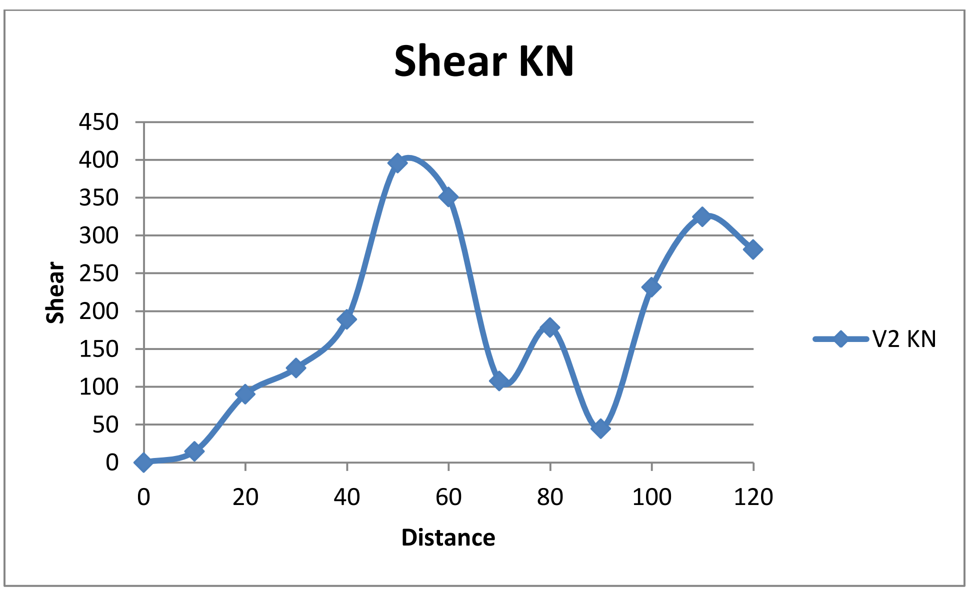


Figure 17: Shear force of interior girder1 for L.L

d) Interior girder 2

Layout Line Distance	M3
m	KN-m
0	0.8529
10	1834.9263
20	2633.4051
30	2425.662
40	1579.9892
50	374.3028
60	0
70	409.4375
80	1546.9595
90	2441.7197
100	2668.9914
110	1827.1512
120	0.7257

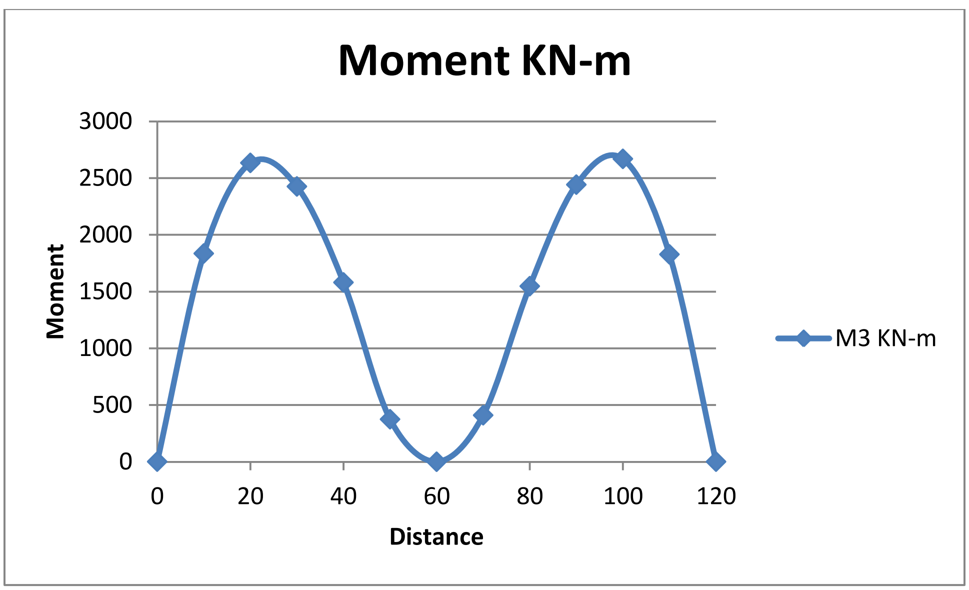


Figure 18: Moment of interior girder2 for L.L.

Layout Line Distance	V2
m	KN
0	0
10	126.948
20	179.956
30	137.694
40	168.555
50	228.585
60	0
70	1.118
80	110.743
90	139.275
100	215.806
110	261.645
120	307.6

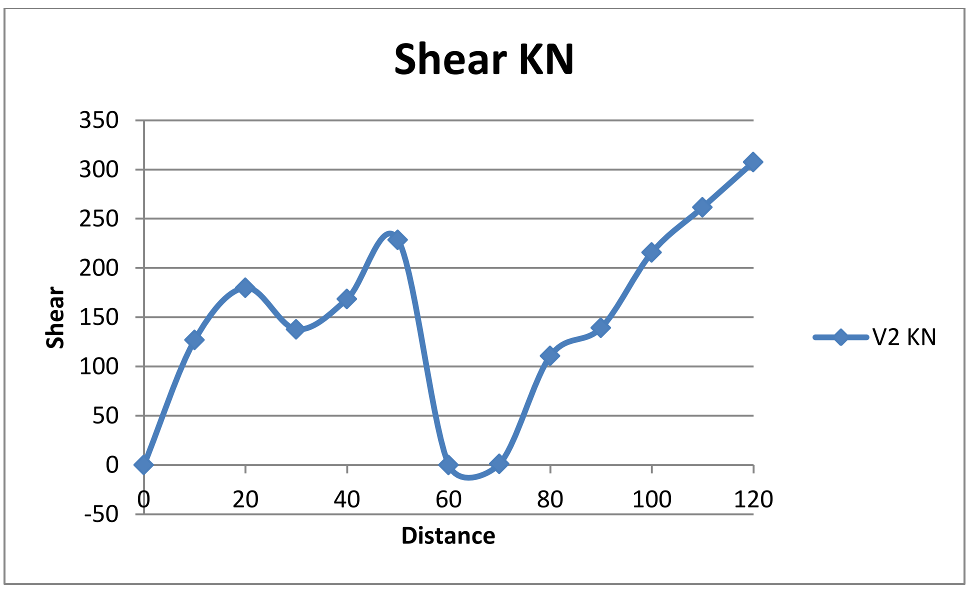


Figure 19: Shear force of interior girder2 for L.L.

e) Right exterior girder

Layout Line Distance	**M3**
m	KN-m
0	0.5559
10	2552.494
20	3710.039
30	3568.7167
40	2681.0336
50	1117.1522
60	0
70	1190.3292
80	2692.3294
90	3514.5491
100	3711.4762
110	2561.9756
120	0.2646

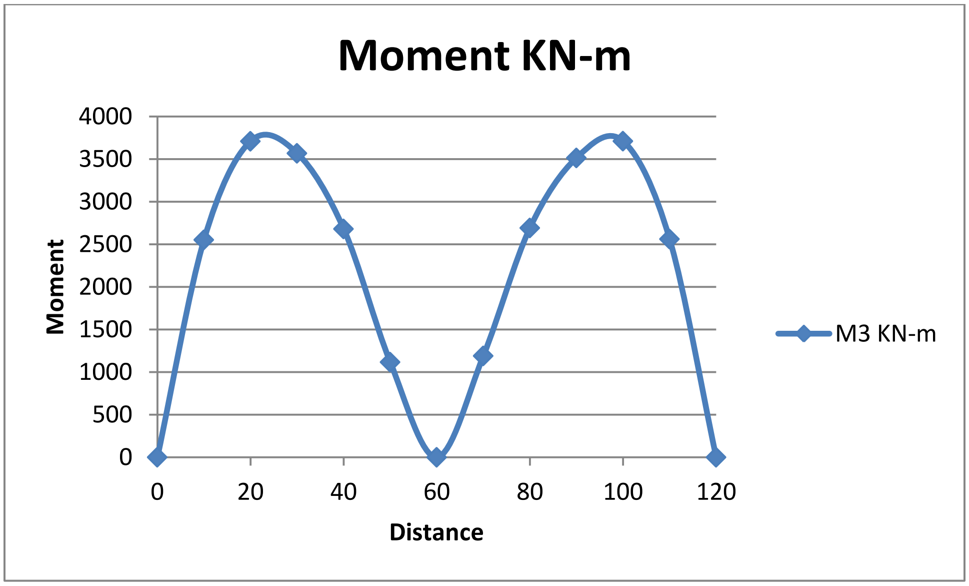


Figure 20: Moment of right exterior girder for L.L.

Layout Line Distance	V2
m	KN
0	7.548
10	25.949
20	57.762
30	130.93
40	205.25
50	263.363
60	317.836
70	0
80	14.434
90	105.935
100	162.743
110	183.566
120	267.735

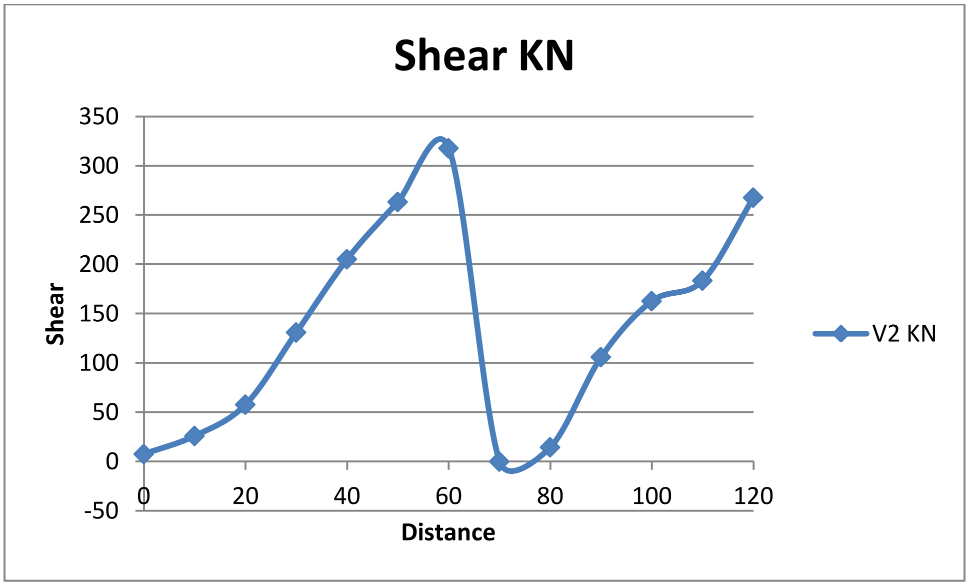


Figure 21: Shear force of right exterior girder for L.L.

5.1.3 Considering moving load

a) For entire bridge

Layout Line Distance	**M3**
m	KN-m
0	1.20E-07
10	10241.8297
20	15325.9216
30	15775.6373
40	12092.6928
50	4932.9849
60	2.1164
70	4932.9849
80	12092.6598
90	15775.6172
97.5	15856.0427
100	15325.754
110	10241.7927
120	2.01E-07

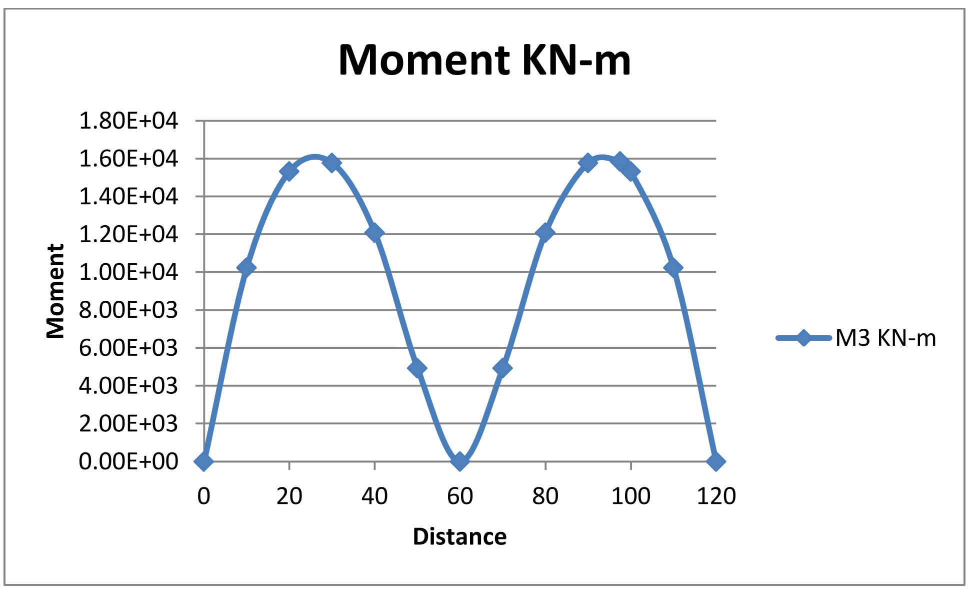


Figure 22: Moment of entire bridge for M.L.

Layout Line Distance	V2
M	KN
0	150.057
10	216.873
20	448.273
30	705.654
40	956.643
50	1237.204
60	1513.518
70	61.614
80	199.473
90	391.159
97.5	591.141
100	635.414
110	956.331
120	1270.003

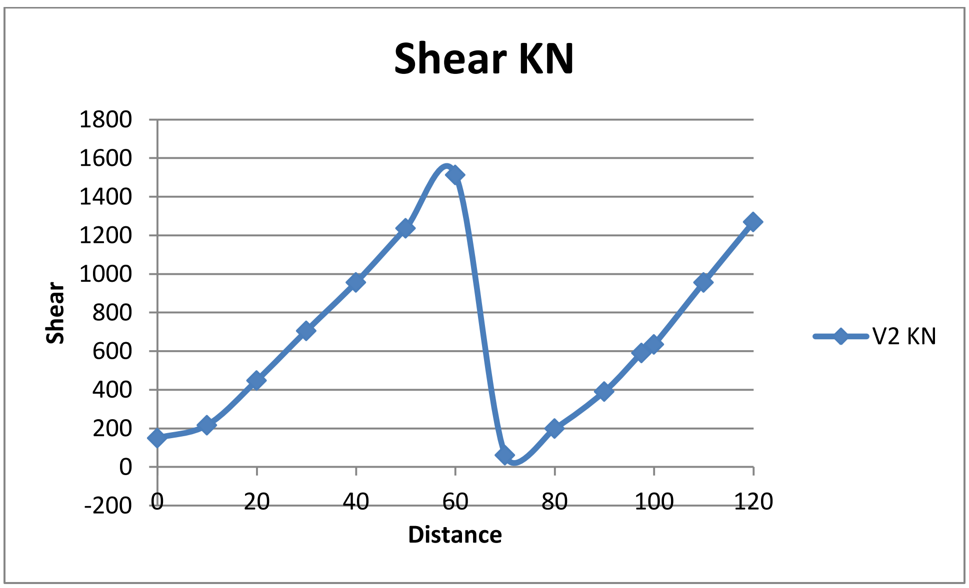


Figure 23: Shear force of entire bridge for M.L.

b) Left exterior girder

Layout Line Distance	M3
m	KN-m
0	0.7046
10	2757.5538
20	4096.6107
30	4211.5024
40	3240.5237
50	1359.5349
60	73.7552
70	1364.2096
80	3246.1392
90	4211.4942
100	4096.6107
110	2765.4774
120	0.7046

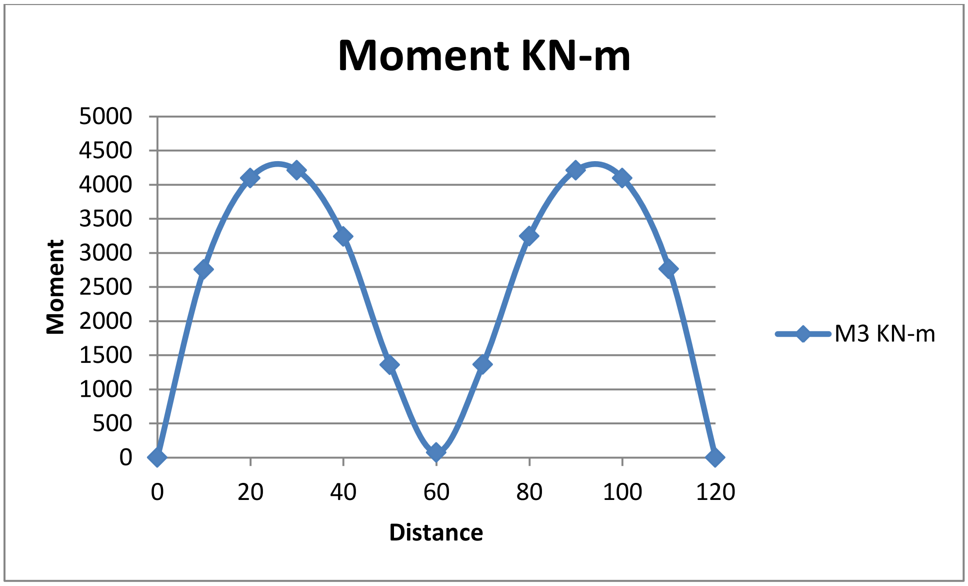


Figure 24: Moment of left exterior girder for M.L.

Layout Line Distance	V2
m	KN
0	40.864
10	64.93
20	126.791
30	138.231
40	215.4
50	297.862
60	375.895
70	13.766
80	30.01
90	115.482
100	126.821
110	275.575
120	298.431

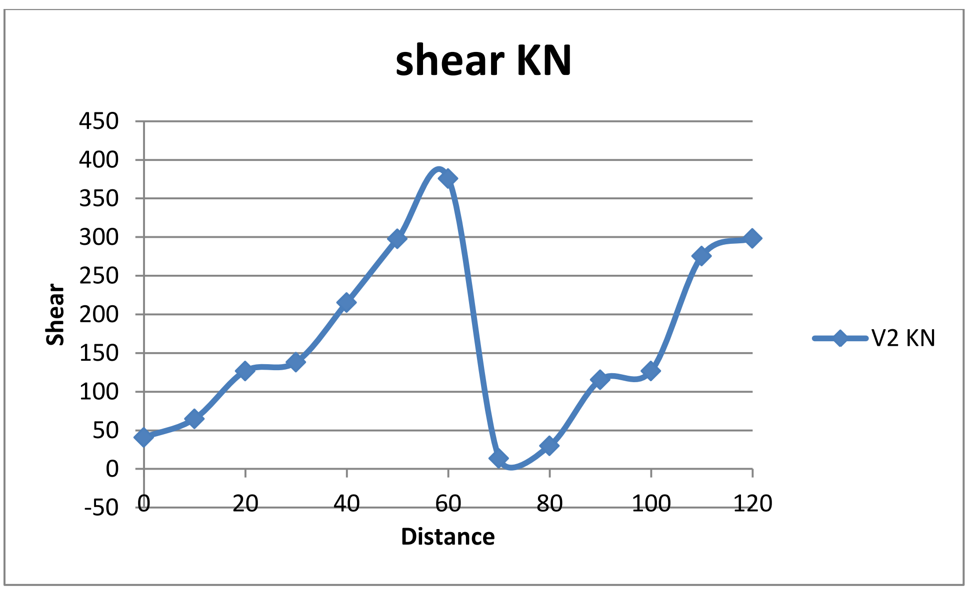


Figure 25:Shear force of left exterior girder for M.L.

c) Interior girder 1

Layout Line Distance	M3
m	KN-m
0	1.3213
10	2705.433
20	4043.6581
30	4160.1354
40	3182.4287
50	1281.8735
60	2.7118
70	1286.8049
80	3182.4292
90	4160.1493
100	4042.1896
110	2705.431
120	1.3213

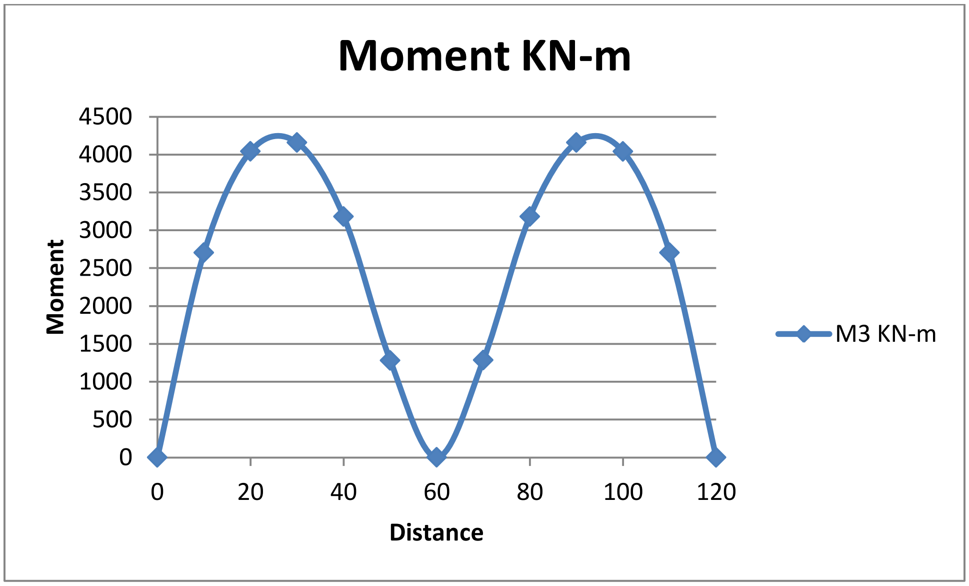


Figure 26: Moment of interior girder1 for M.L.

Layout Line Distance	V2
m	KN
0	38.323
10	61.051
20	119.59
30	186.317
40	346.532
50	337.197
60	511.818
70	24.793
80	59.525
90	211.015
100	173.969
110	337.926
120	425.667

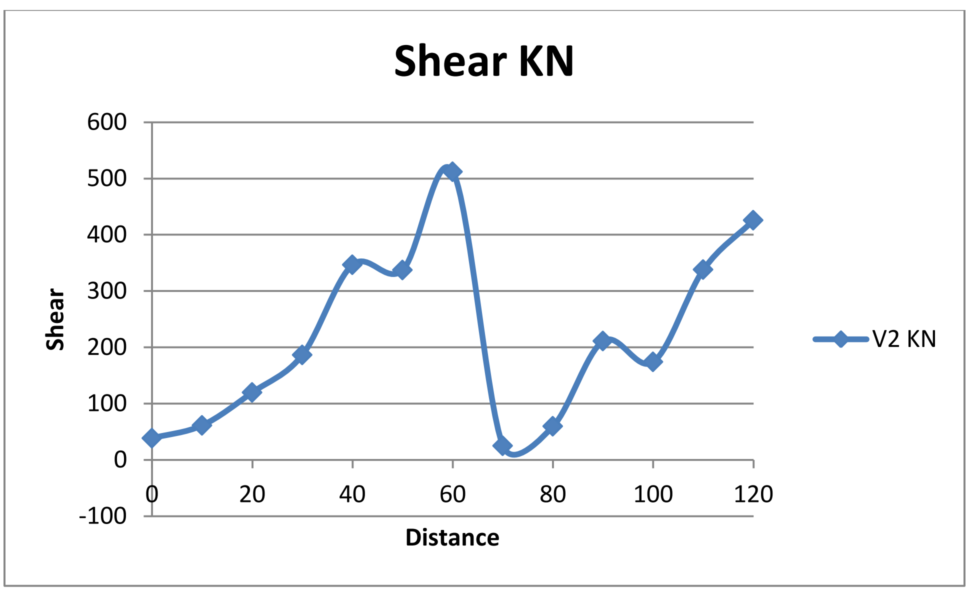


Figure 27: Shear force of interior girder1 for M.L.

d) Interior girder 2

Layout Line Distance	M3
m	KN-m
0	1.3213
10	2705.433
20	4043.6581
30	4160.1354
40	3182.4287
50	1286.8049
60	2.7118
70	1281.8735
80	3178.3363
90	4160.1493
100	4043.66
110	2705.4311
120	1.3213

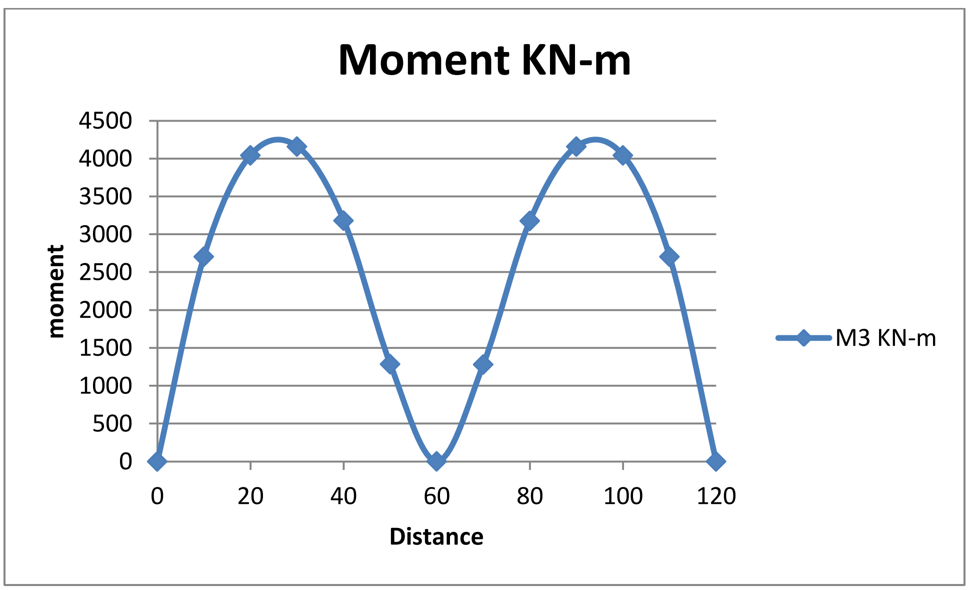


Figure 28: Moment of interior girder2 for M.L.

Layout Line Distance	V2
m	KN
0	38.323
10	61.051
20	119.59
30	186.317
40	346.532
50	418.923
60	511.818
70	134.9
80	170.486
90	211.015
100	266.732
110	337.926
120	425.667

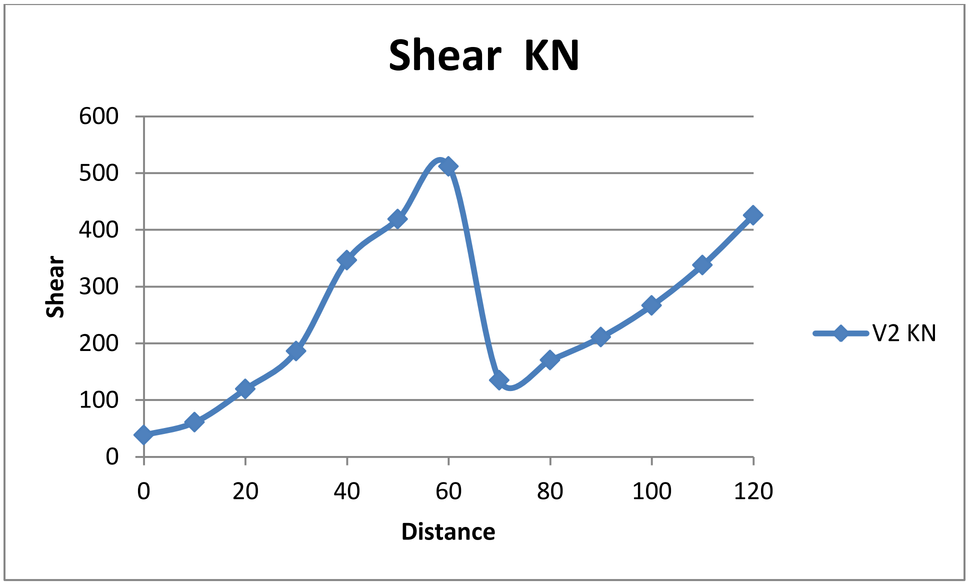


Figure 29: Shear force of interior girder2 for M.L.

e) Right exterior girder

Layout Line Distance	M3
m	KN-m
0	0.7046
10	2765.4774
20	4099.406
30	4211.5024
40	3240.5237
50	1359.5349
60	73.7552
70	1364.2096
80	3240.5201
90	4212.6071
100	4096.6107
110	2757.5487
120	0.7046

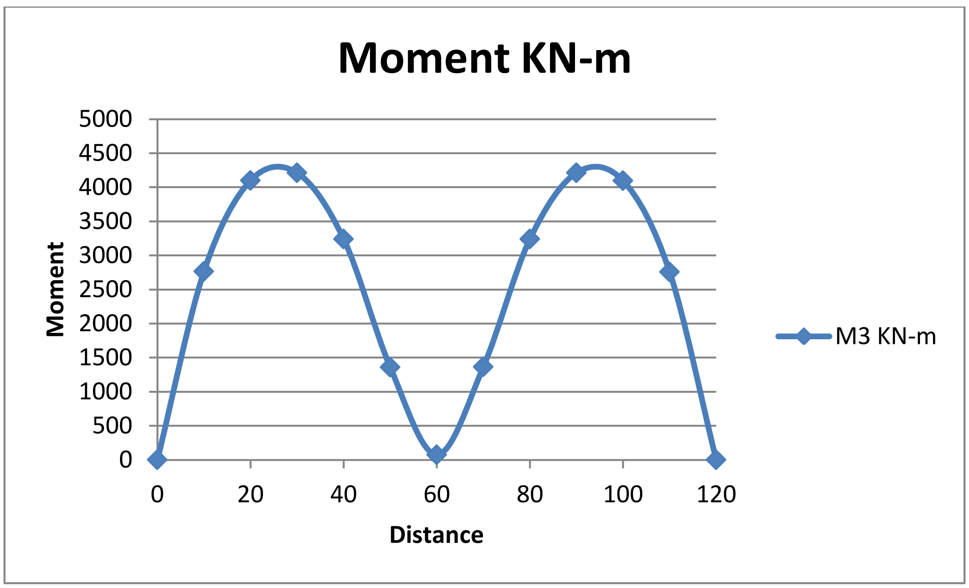


Figure 30: Moment of right exterior girder for M.L.

Layout Line Distance	V2
m	KN
0	40.864
10	41.989
20	76.132
30	138.231
40	215.4
50	297.862
60	20.773
70	13.766
80	63.878
90	70.349
100	126.821
110	202.936
120	298.431

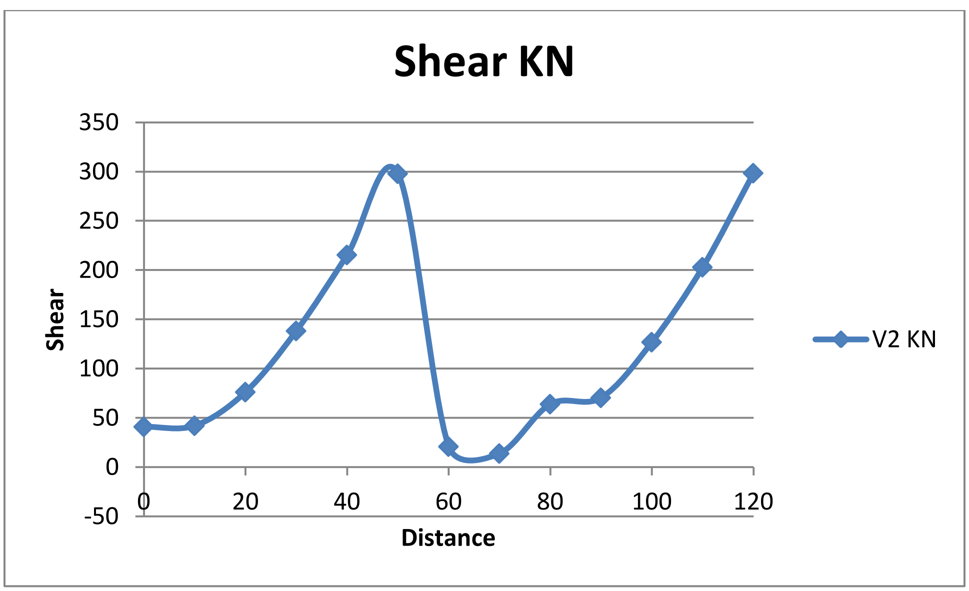


Figure 31: Shear force of right exterior girder for M.L.

5.1.4 Considering seismic load

a) For entire bridge

Layout Line Distance	M2
m	KN-m
0	-1.04E-07
10	-313.5365
20	-1928.2912
30	-4844.2643
40	-9061.4557
50	-14579.8655
60	-21399.4936
70	-14579.8655
80	-9061.4557
90	-4844.2643
100	-1928.2912
110	-313.5365
120	9.48E-08

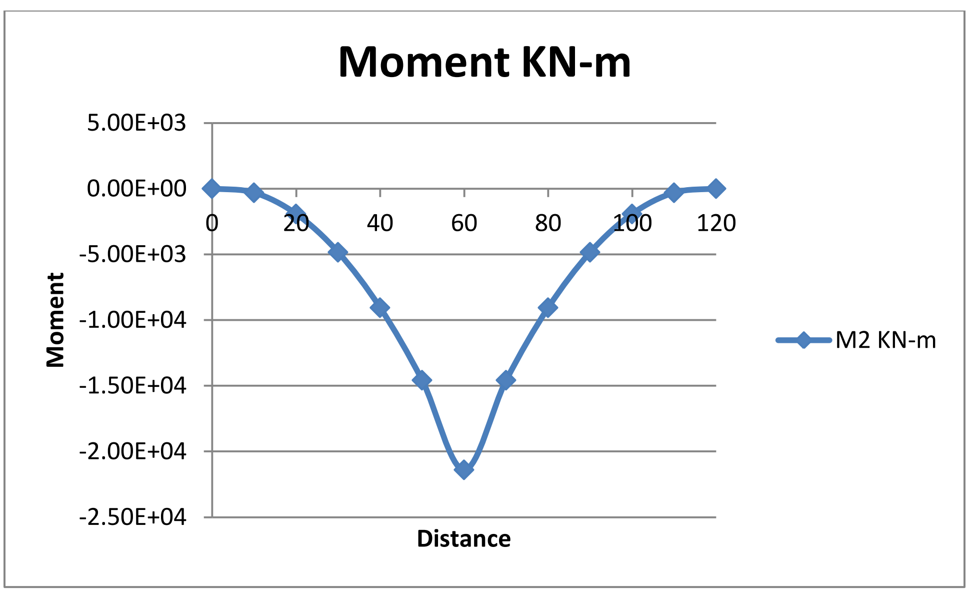


Figure 32: Moment of entire bridge for S.L.

Layout Line Distance	V3
m	KN
0	-64.02
10	270.392
20	559.59
30	894.0053
40	1273.63
50	1608.02
60	-1902.13
70	-1562.84
80	-1273.64
90	-939.132
100	-604.79
110	-270.38
120	-64.022

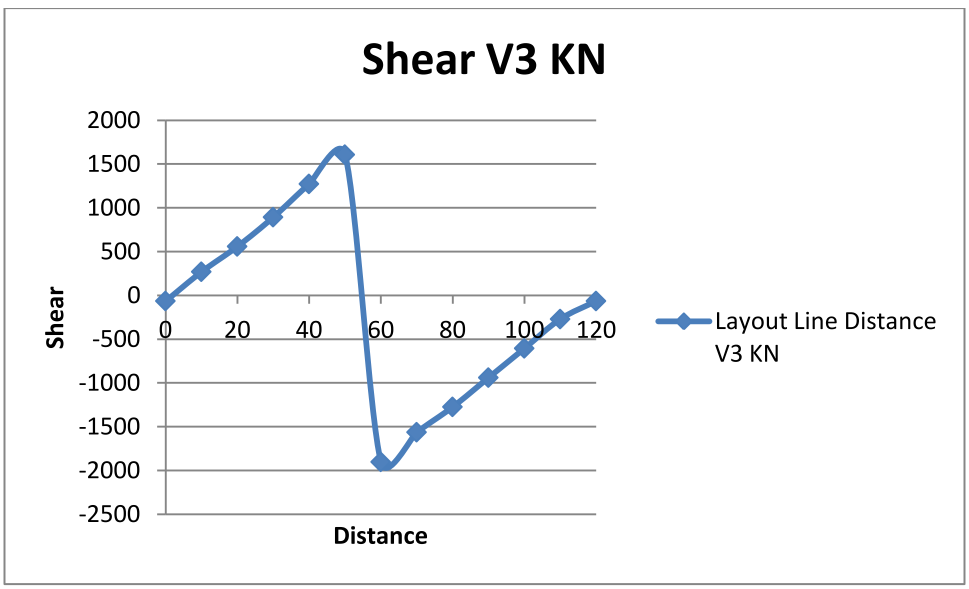


Figure 33: Shear force of entire bridge for S.L.

b) Left exterior girder

Layout Line Distance	M2
m	KN-m
0	-0.1124
10	-1.1864
20	19.2581
30	25.0783
40	84.8192
50	180.2828
60	202.7761
70	263.8668
80	84.8192
90	25.0783
100	-7.9048
110	-6.1592
120	-0.1124

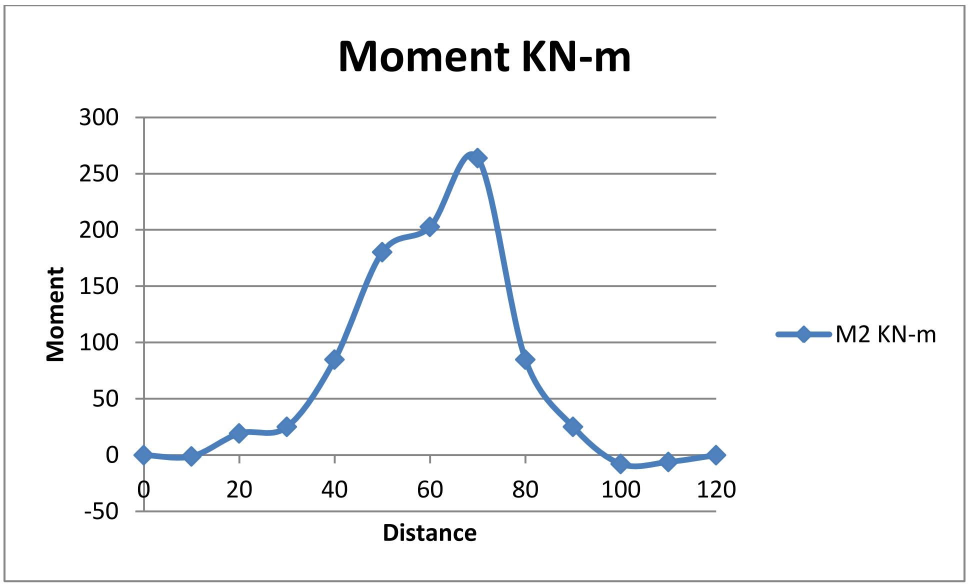


Figure 34: Moment of left exterior girder for S.L.

Layout Line Distance	V3
m	KN
0	-5.244
10	16.99
20	31.815
30	48.183
40	66.82
50	84.115
60	-142.523
70	-74.485
80	-66.82
90	-48.183
100	-30.575
110	-14.578
120	5.244

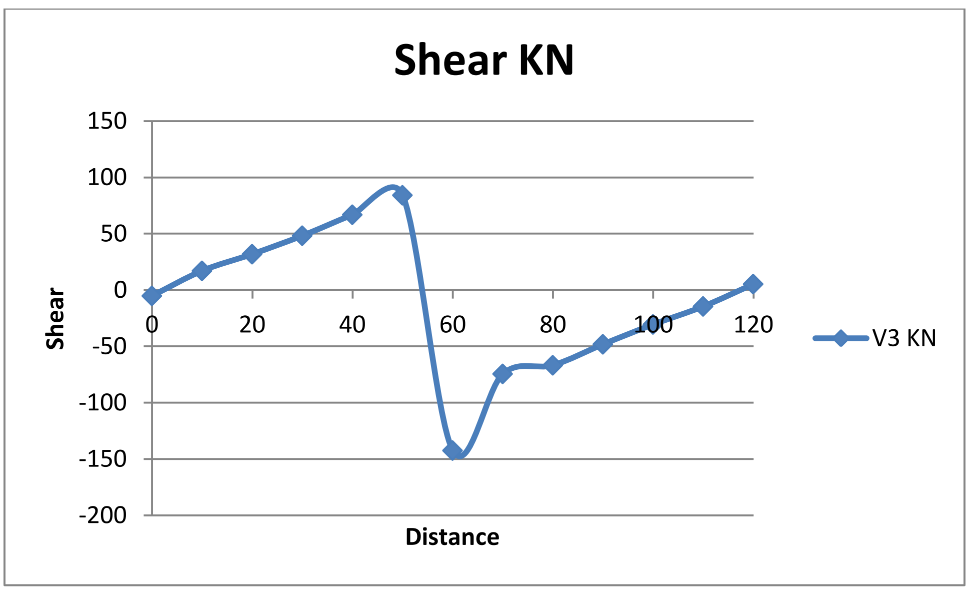
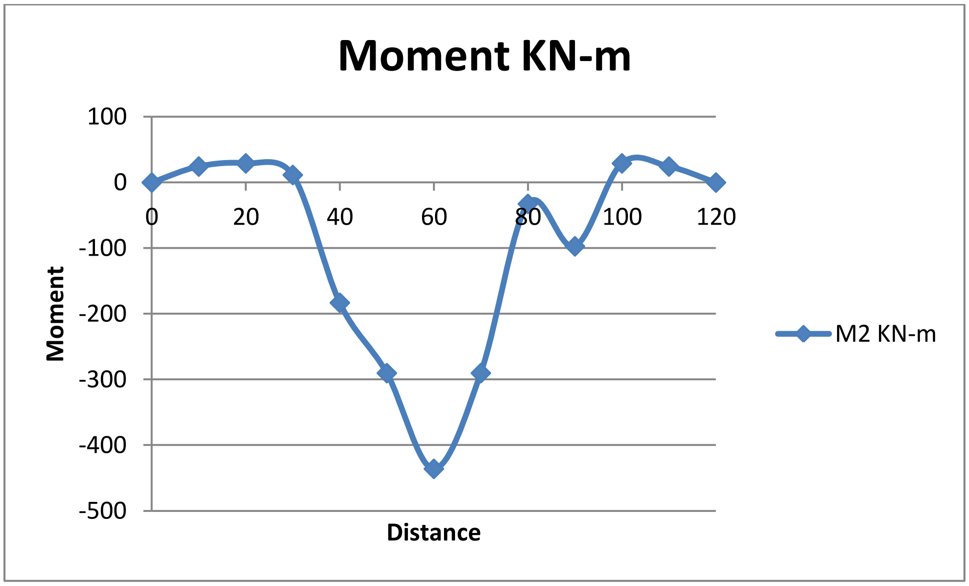


Figure 35: Shear force of left exterior girder for S.L.

c) Interior girder 1

Layout Line Distance	M2
m	KN-m
0	-0.2383
10	24.148
20	28.9316
30	11.2471
40	-183.2317
50	-290.2704
60	-435.9536
70	-290.2704
80	-32.7778
90	-97.3222
100	28.9316
110	24.148
120	-0.2383



SS

Figure 36: Moment of interior girder1 for S.L.

Layout Line Distance	V3
m	KN
0	-7.211
10	35.615
20	85.851
30	135.873
40	172.172
50	219.938
60	226.59
70	-219.938
80	-186.8
90	-125.748
100	-85.851
110	-35.615
120	7.211

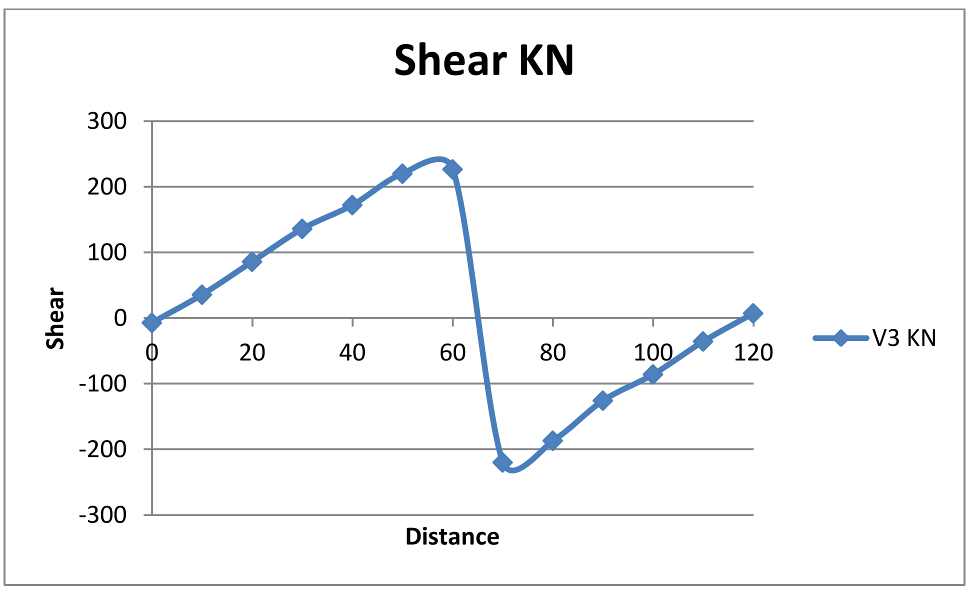


Figure 37: Shear force of interior girder1 for S.L.

d) Interior girder 2

Layout Line Distance	M2
m	KN-m
0	-0.2383
10	24.148
20	-36.3157
30	-97.3222
40	-183.2317
50	-290.2704
60	-435.9536
70	-95.613
80	-183.2317
90	-97.3222
100	-36.3157
110	7.5253
120	-0.2383

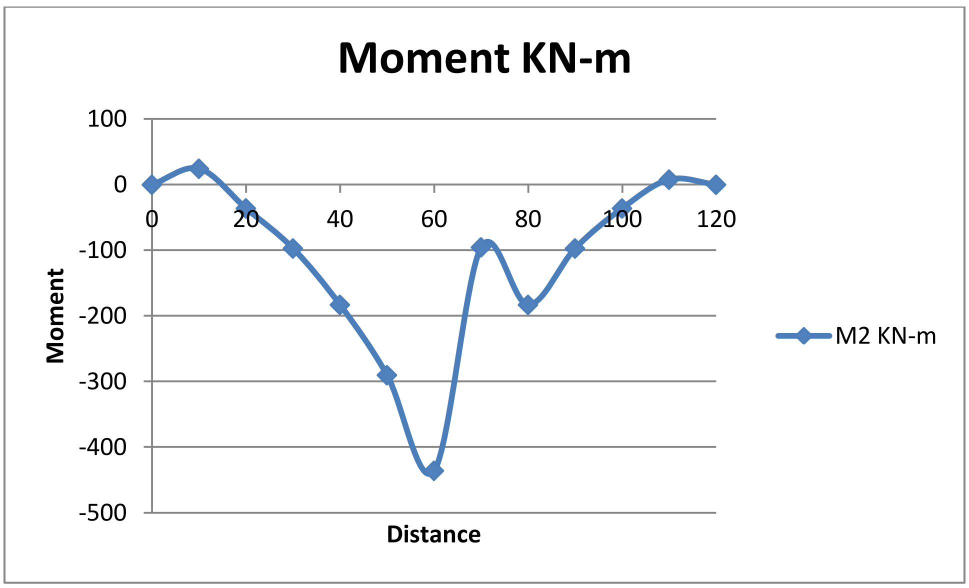


Figure 38: Moment of interior girder2 for S.L.

Layout Line Distance	V3
m	KN
0	-7.211
10	35.615
20	78.295
30	125.748
40	172.172
50	219.938
60	-226.59
70	-238.364
80	-172.172
90	-125.748
100	-78.295
110	-29.231
120	7.211

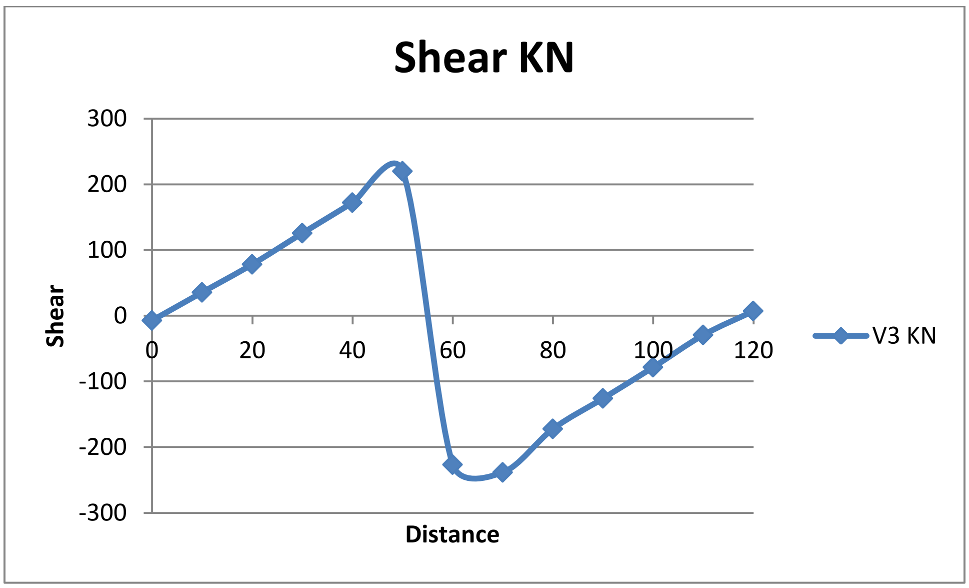


Figure 39: Shear force of interior girder2 for S.L.

e) Right exterior girder

Layout Line Distance	M2
m	KN-m
0	-0.1125
10	-1.1864
20	-7.9048
30	25.0783
40	84.8192
50	180.2828
50	263.8668
60	202.7761
70	263.8668
80	148.56
90	70.87
100	19.2581
110	-1.1864
120	-0.1124

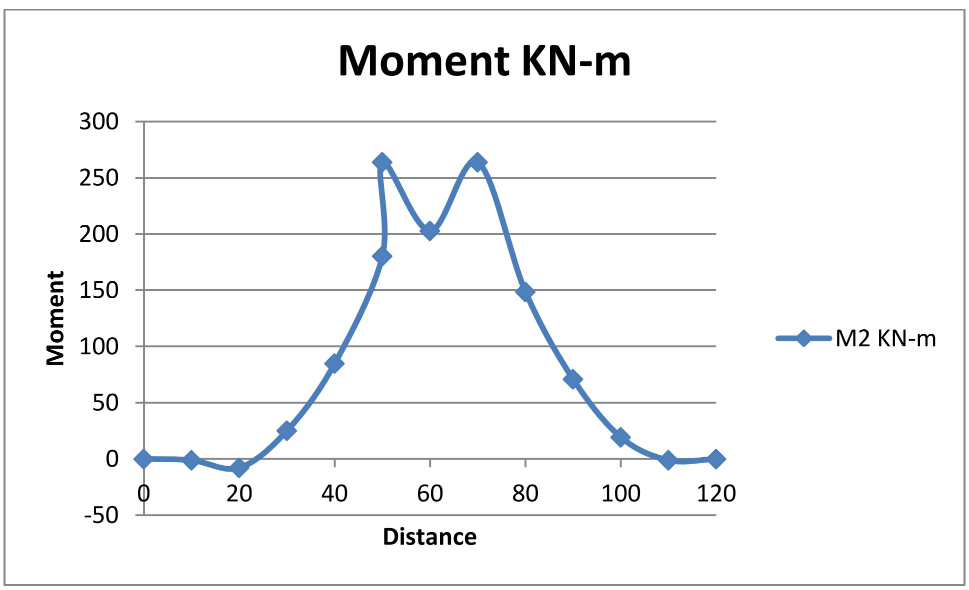


Figure 40: Moment of right exterior girder for S.L

Layout Line Distance	V3
m	KN
0	-5.244
10	16.99
20	30.575
30	48.183
40	66.82
50	84.115
50	74.485
60	142.523
70	-74.485
80	-60.988
90	-46.854
100	-31.815
110	-16.99
120	5.244

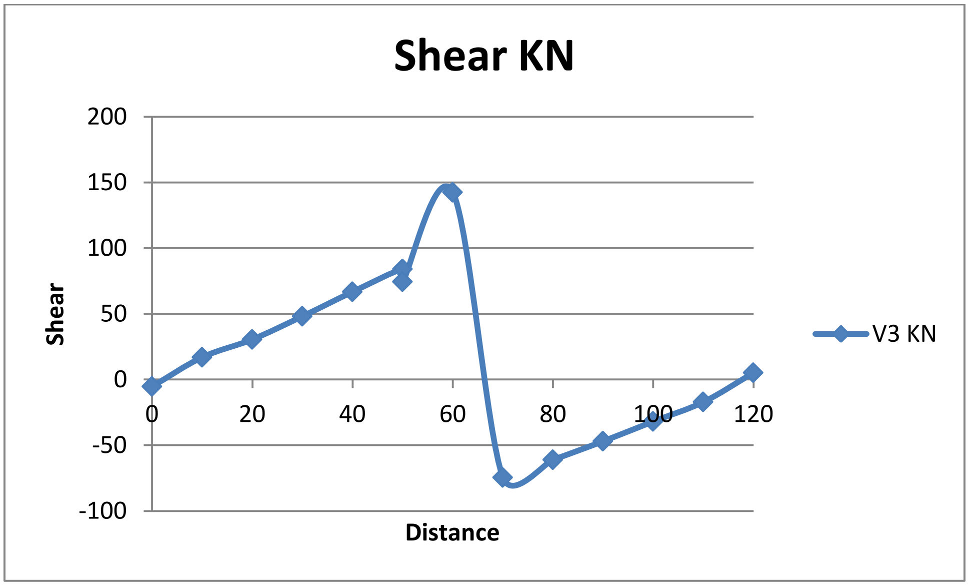
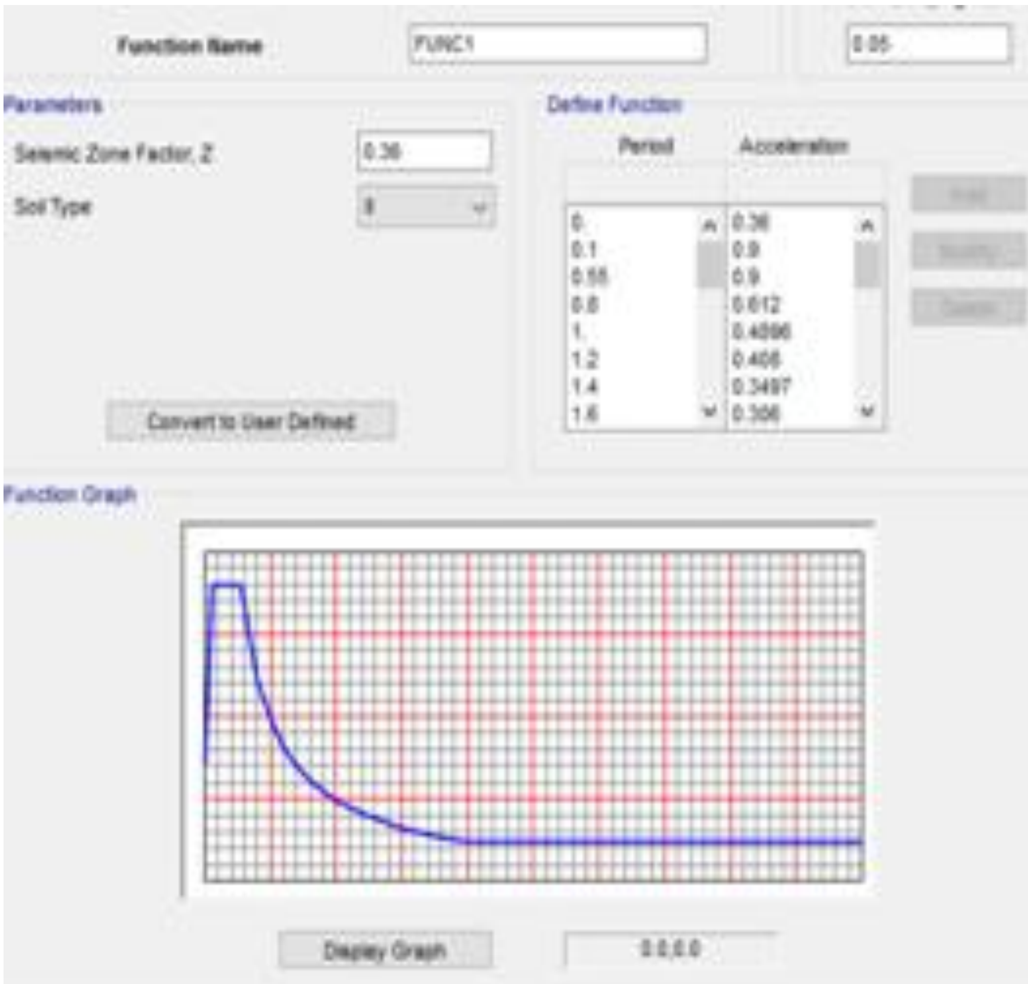


Figure 41: Shear force of right exterior girder for S.L.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FUNC1
0.05
Parameters
Seismic Zone Factor, Z
0.36
Soil Type
Define Function
Period
Acceleration
0.
0.1
0.55
0.8
1.
1.2
1.4
1.6
0.36
0.9
0.9
0.612
0.4896
0.408
0.3497
0.306
Convert to User Defined
Function Graph
Display Graph

a) For entire bridge

Layout Line Distance	M2
m	KN-m
0	1.4231
10	414.5421
20	1921.8696
30	4296.1466
40	7329.5171
50	10859.4321
60	14800.1292
70	10860.5745
80	7329.5175
90	4296.1466
100	1925.2517
110	418.3712
120	1.4231

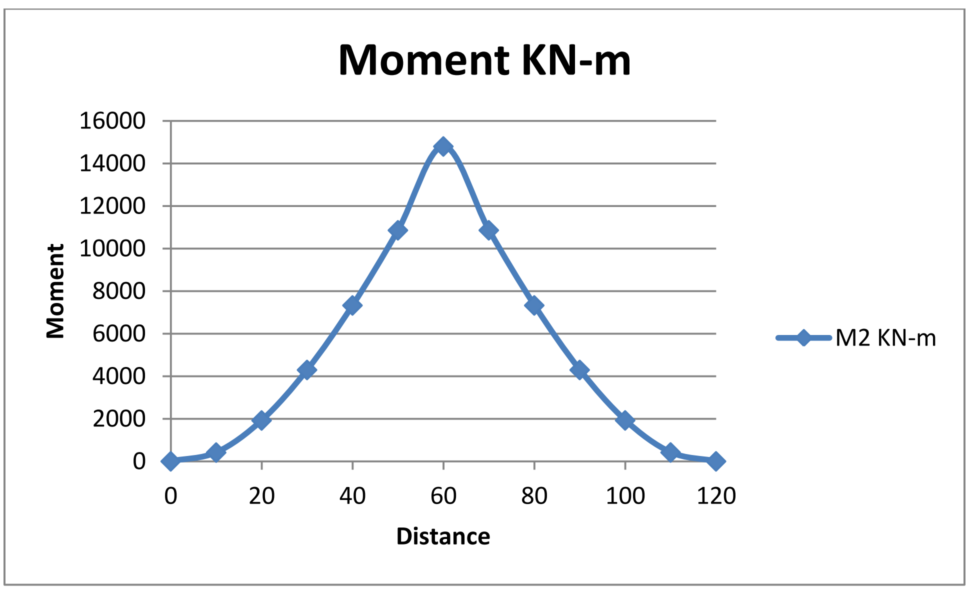


Figure 42: Moment of entire bridge for RSA

Layout Line Distance	V3
m	KN
0	50.0262
10	271.011
20	572.011
30	810.063
40	1016.765
50	1145.25
60	1315.55
70	1163.96
80	1016.477
90	810.06
100	609.28
110	316.35
120	50.0262

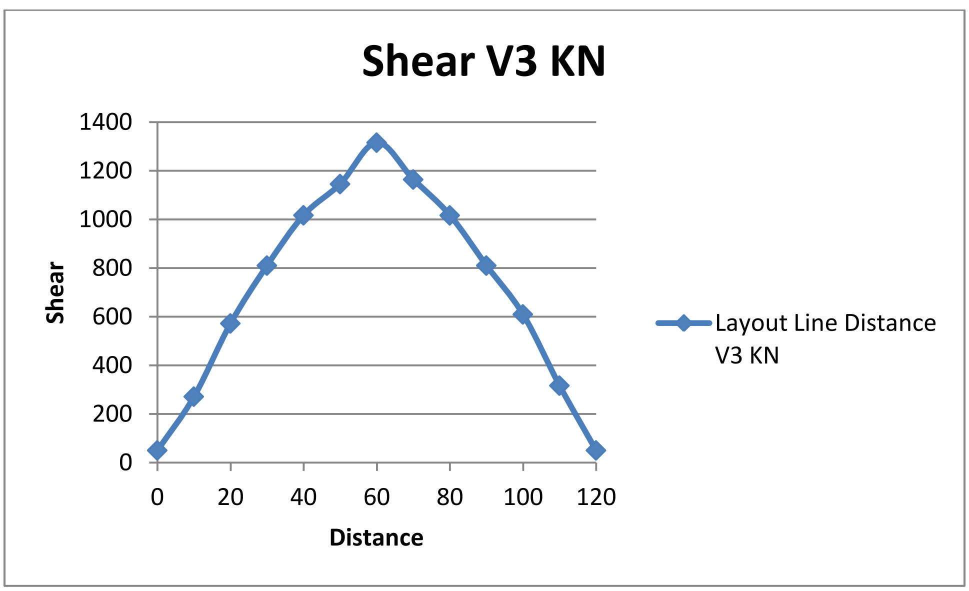


Figure 43: Shear force of entire bridge for RSA

b) Left exterior girder

Layout Line Distance	M3
m	KN-m
0	0.0303
10	170.9683
20	254.6212
30	236.4672
40	136.4583
50	47.3293
60	215.4187
70	53.1021
80	125.6632
90	227.1936
100	246.4779
110	170.9674
120	0.0303

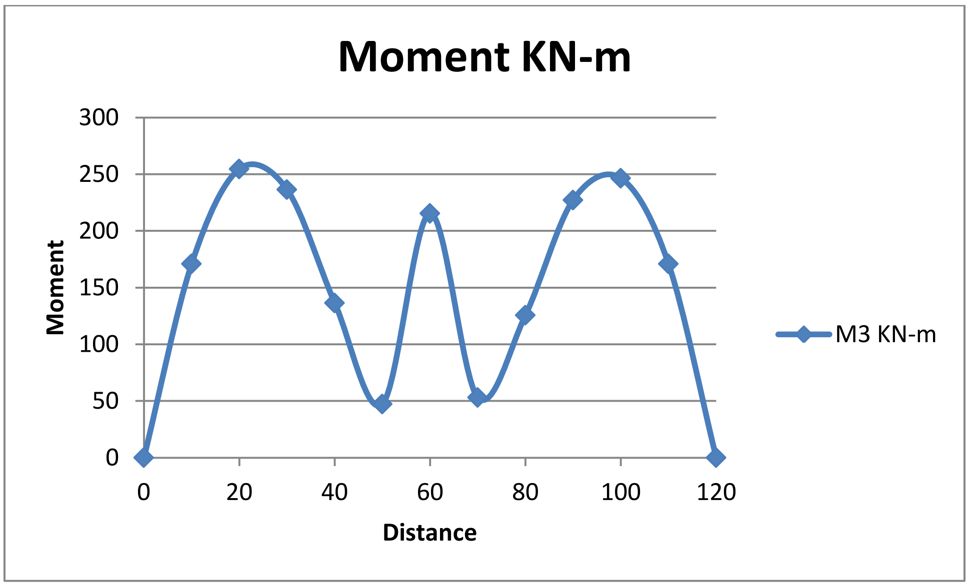


Figure 44: Moment of left exterior girder for RSA

Layout Line Distance	V3
m	KN
0	3.16
10	16.616
20	26.517
30	36.703
40	45.539
50	52.381
60	81.623
70	44.144
80	40.278
90	35.052
100	27.278
110	16.616
120	3.16

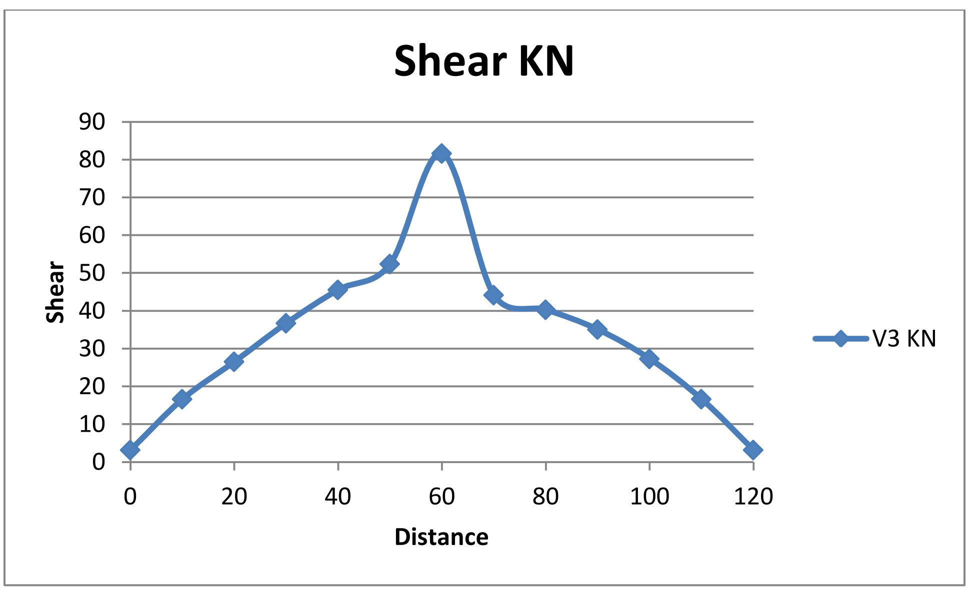


Figure 45: Shear force of left exterior girder for RSA

c) interior girder 1

Layout Line Distance	M2
M	KN-m
0	0.3172
10	24.114
20	28.4777
30	15.6792
40	140.0708
50	209.5481
60	293.9273
70	90.5548
80	140.0708
90	78.9342
100	28.4777
110	24.114
120	0.3172

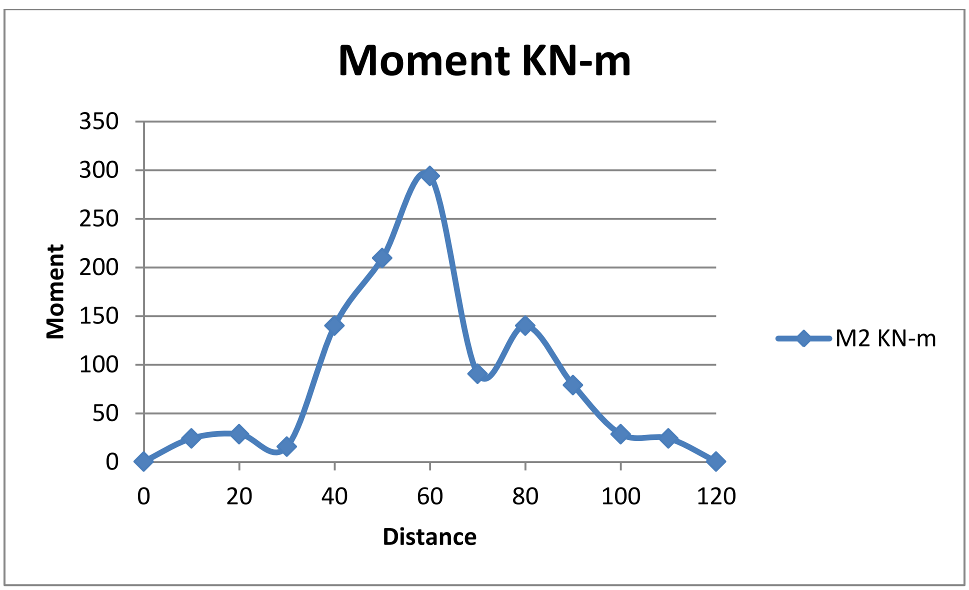


Figure 46: Moment of interior girder1 for RSA

Layout Line Distance	V3
m	KN
0	5.19
10	36.018
20	73.95
30	104.16
40	119.701
50	137.902
60	130.172
70	149.284
80	119.701
90	97.869
100	73.95
110	36.018
120	5.19

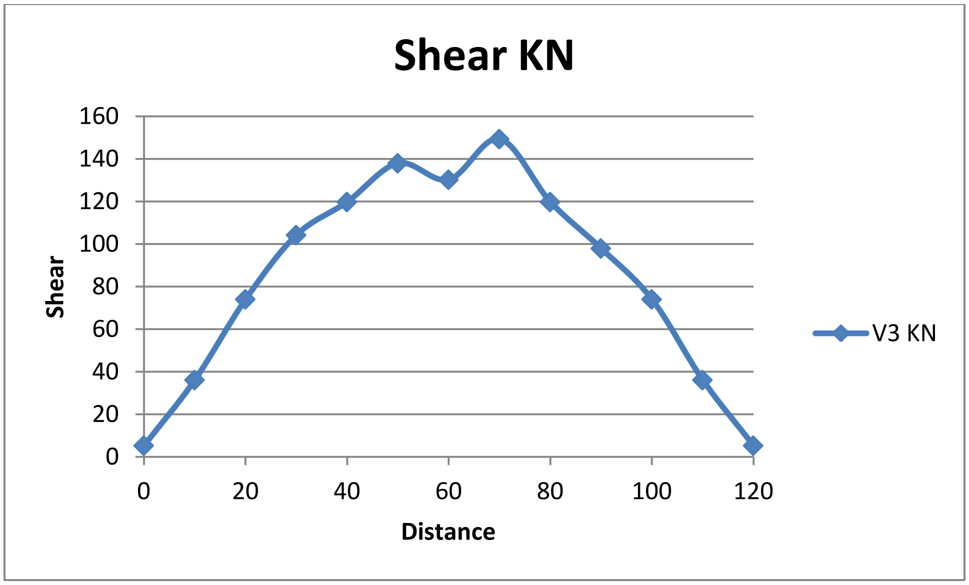


Figure 47: Shear force of interior girder1 for RSA

d) interior girder 2

Layout Line Distance	M2
m	KN-m
0	0.3172
10	24.114
20	28.4777
30	15.6792
40	39.0725
50	90.5547
60	293.9273
70	90.5548
80	140.0708
100	28.4777
110	24.114
120	0.3172

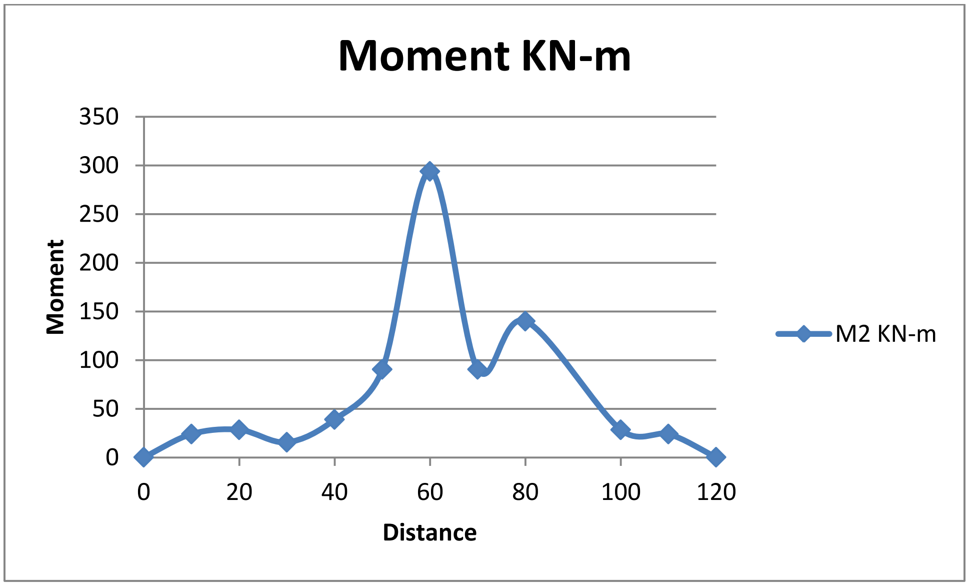


Figure 48: Moment of interior girder2 for RSA

Layout Line Distance	V3
m	KN
0	5.19
10	36.018
20	73.95
30	104.16
40	128.636
50	149.284
60	130.172
70	149.284
80	119.701
100	73.95
110	36.018
120	5.19

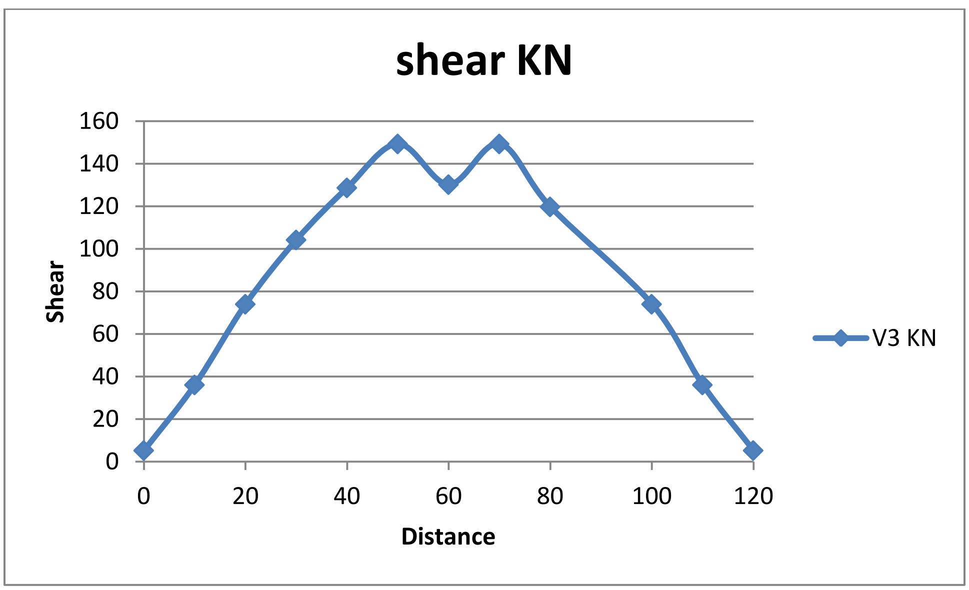


Figure 49: Shear force of interior girder2 for RSA

e) Right exterior girder

Layout Line Distance	M3
m	KN-m
0	0.0303
10	170.9679
20	254.6212
30	236.4677
40	136.4582
50	47.3296
60	215.4185
70	47.3296
80	125.6631
90	227.1934
100	254.6213
110	170.9676
120	0.0303

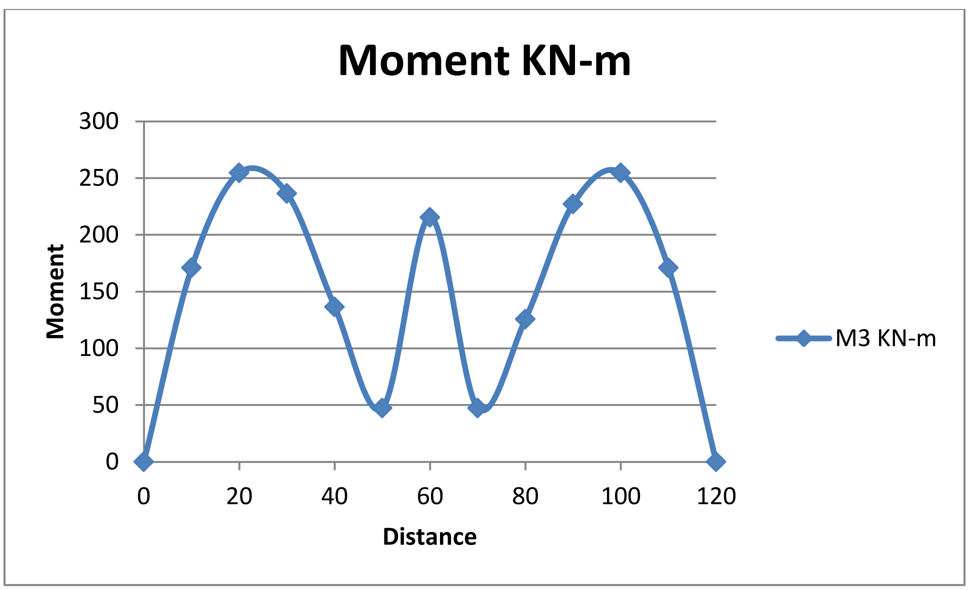


Figure 50: Moment of right exterior girder for RSA

Layout Line Distance	V3
m	KN
0	3.16
10	16.616
20	26.517
30	36.703
40	45.539
50	52.381
60	81.623
70	52.381
80	40.278
90	35.052
100	26.517
110	16.616
120	3.16

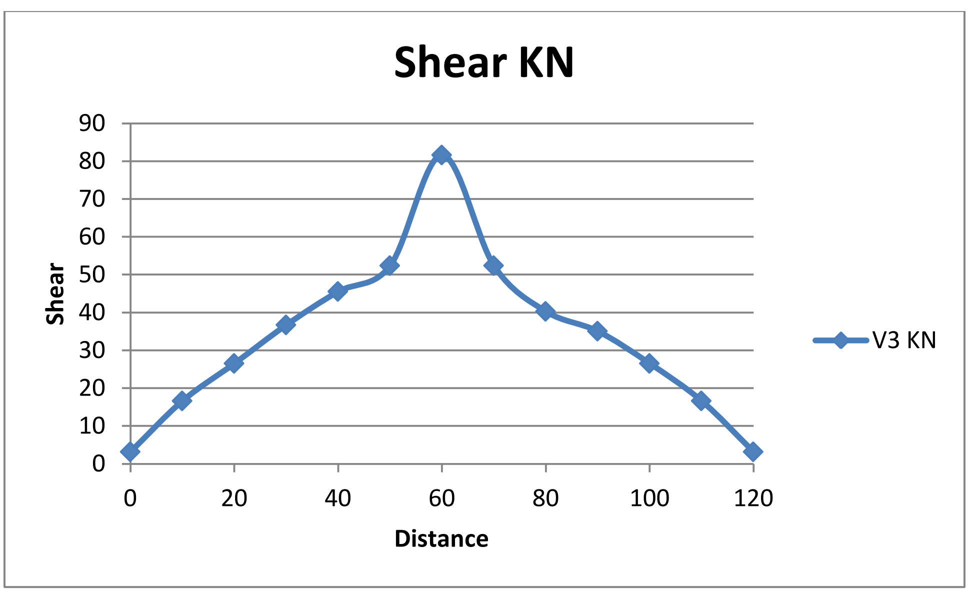
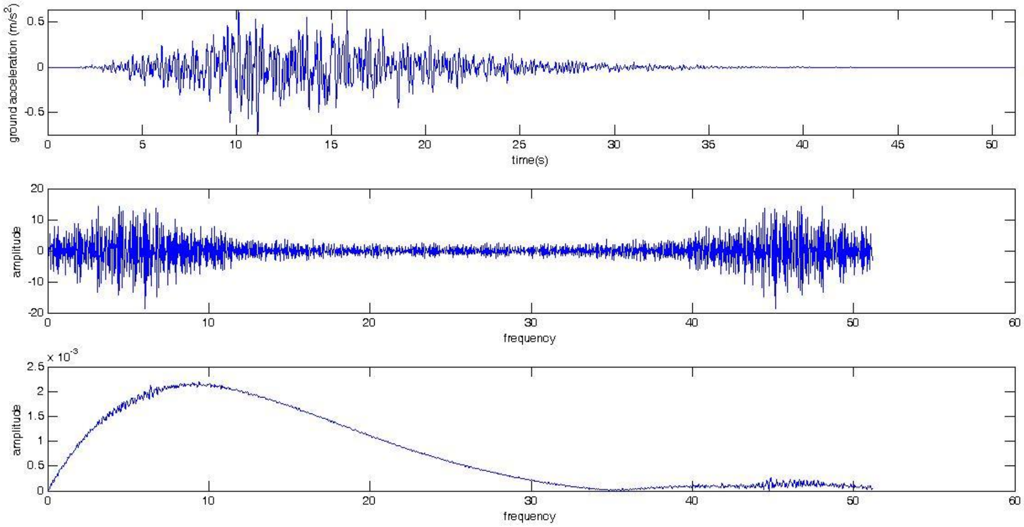
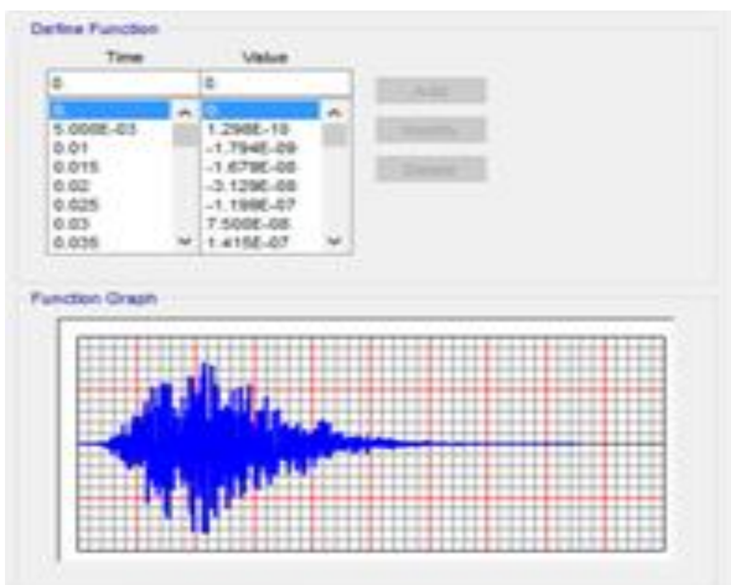


Figure 51: Shear force of right exterior girder for RSA

Chapter 7: Time History Analysis

7.1 For ground motion 1





Layout Line Distance	M2
m	KN-m
0	1.194
10	-176.16
20	-1984.36
30	-5779.49
40	-11784.7
50	-20046
60	-30404.5
70	-20046
80	-11783.2
90	-5778.34
100	-1984.36
110	-176.16
120	1.194

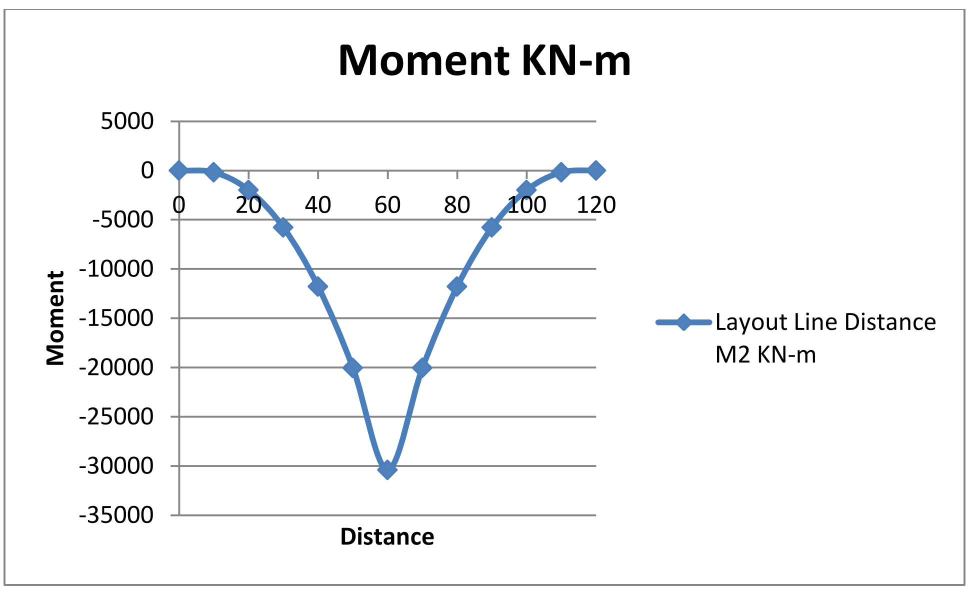


Figure 52: Moment for time history analysis for GM 1

Layout Line Distance	V3
M	KN
0	-672.83
10	759.37
20	1102.44
30	336.6
40	1913.079
50	1171.15
60	2702.62
70	-1171.15
80	-756.94
90	-333.42
100	66.99
110	405.6
120	672.83

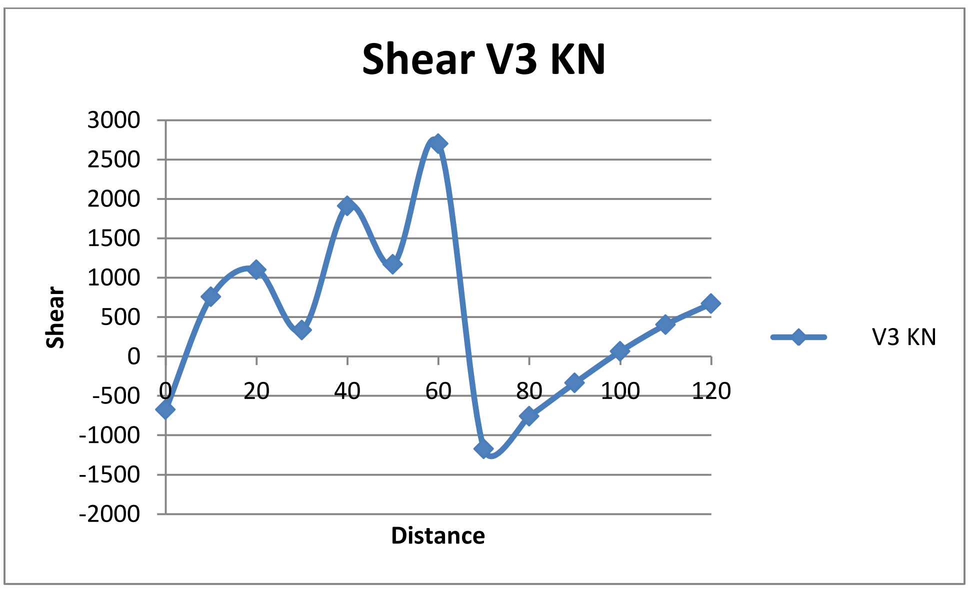
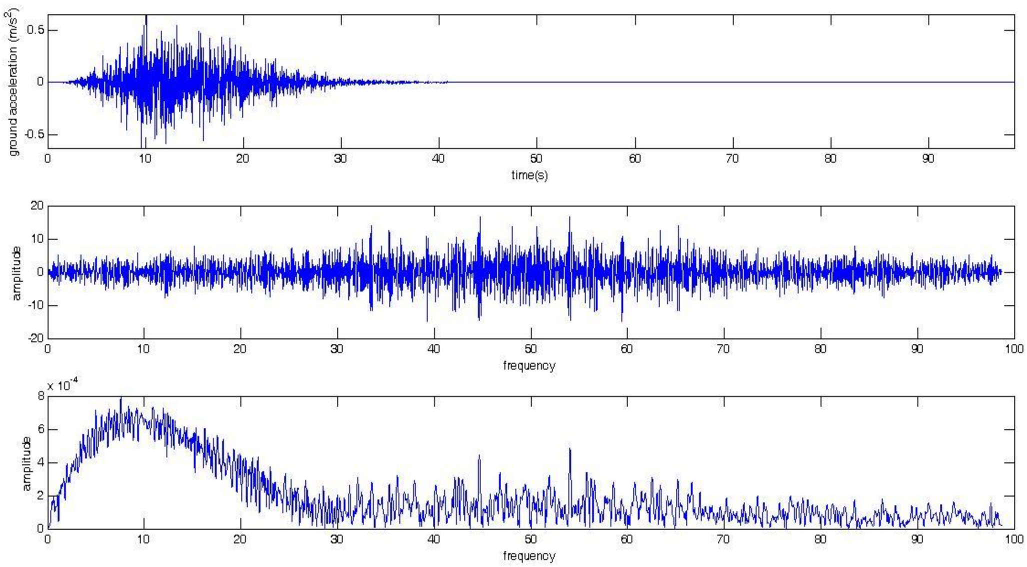
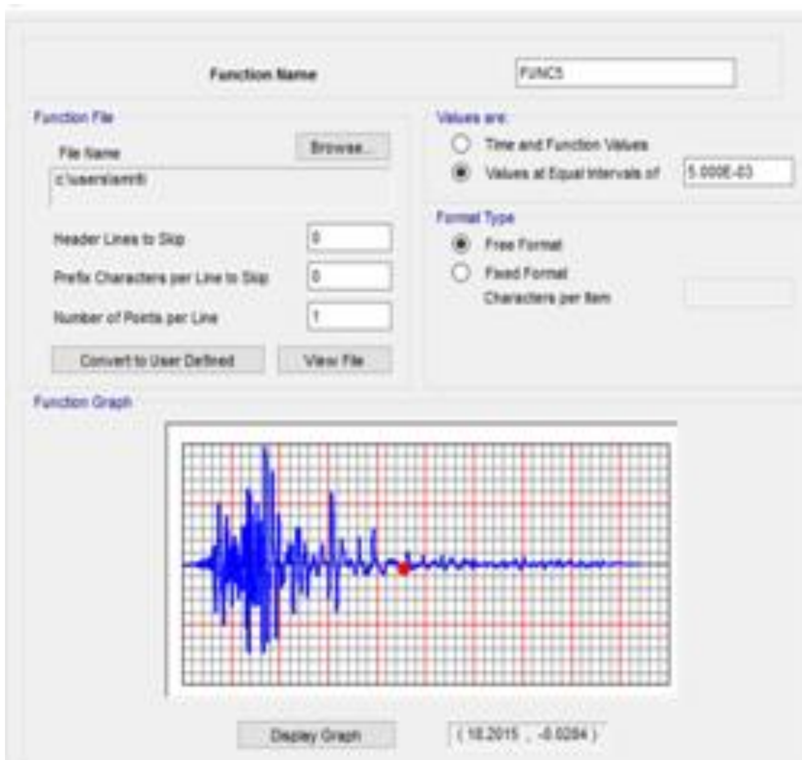


Figure 53: Shear force for time history analysis for GM 1

7.2 For ground motion 2





Layout Line Distance	M2
M	KN-m
0	-0.4208
10	406.3018
20	2893.7037
30	7602.0183
40	14600.8588
50	23874.1774
60	35276.1237
70	23874.1771
80	14601.5475
90	7601.8683
100	2892.8376
110	406.3019
120	-0.4208

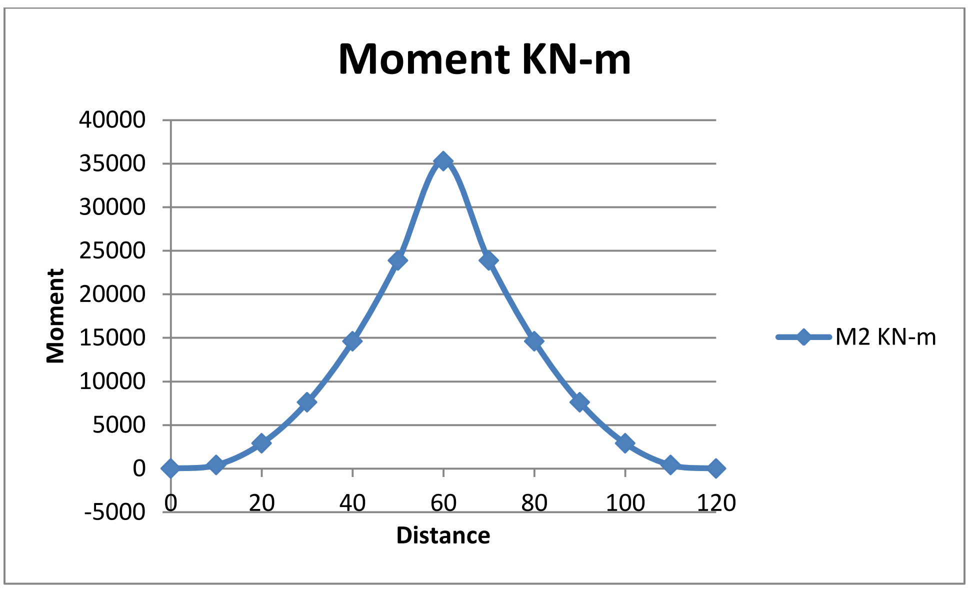


Figure 54: Moment for time history analysis for GM 2

Layout Line Distance	**V3**
m	KN
0	148.54
10	-413.33
20	-1064.17
30	-1775.4
40	-2433.55
50	-2854.61
60	-3135.64
70	2856.7
80	2535.5
90	1778.31
100	1064.17
110	413.33
120	-148.54

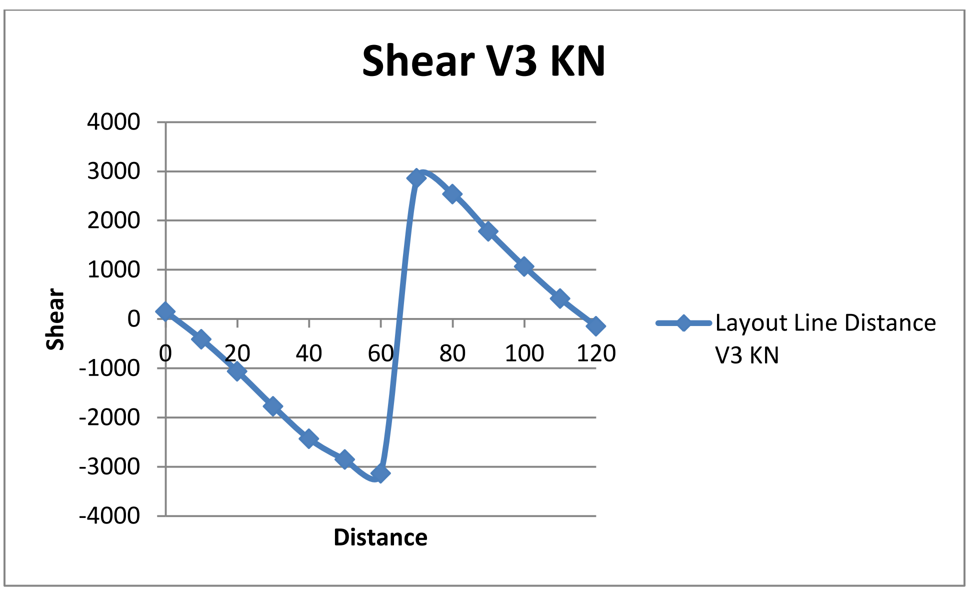
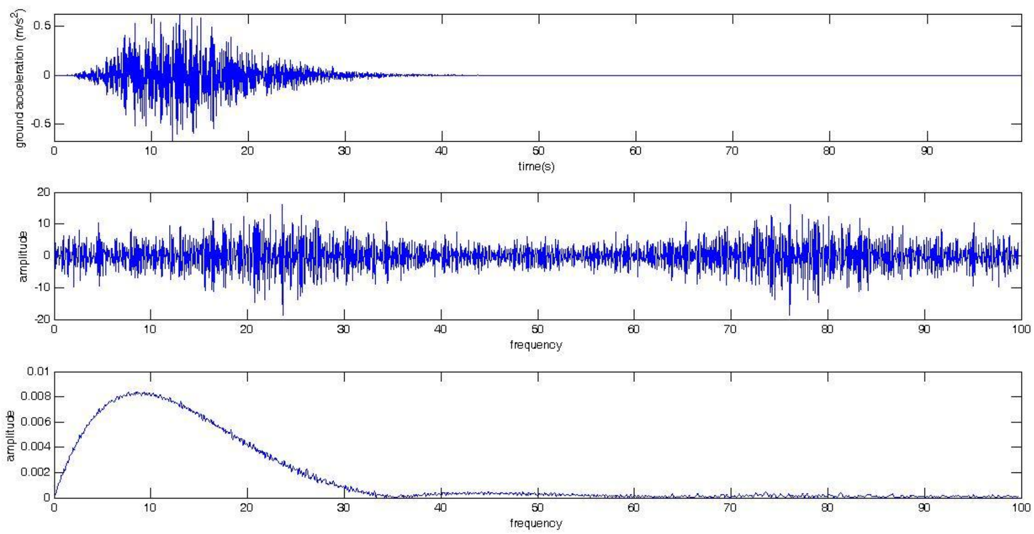
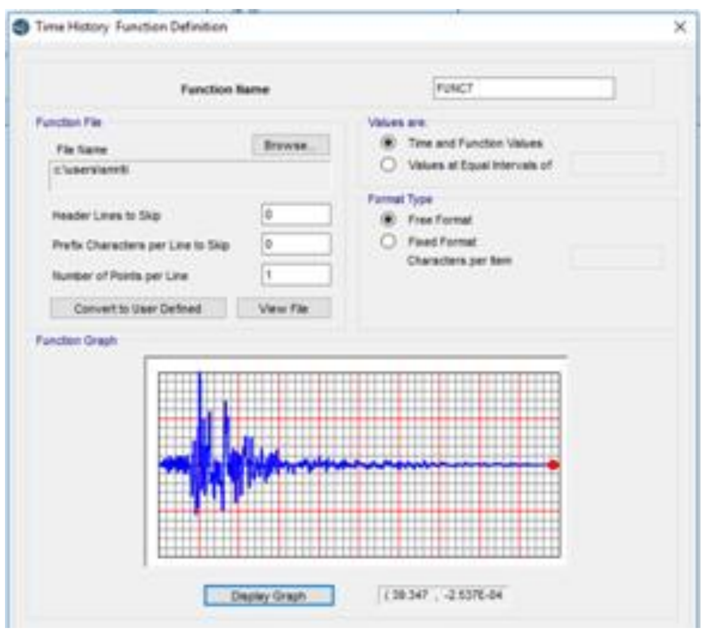


Figure 55: Shear force for time history analysis for GM2

7.3 For ground motion 3





‘

Layout Line Distance	M2
m	KN-m
0	-0.1984
10	548.2786
20	3109.2536
30	7783.3092
40	14589.989
50	23473.9177
60	34277.0287
70	23472.8067
80	14589.9898
90	7783.3105
100	3109.2544
110	548.2789
120	-0.1984

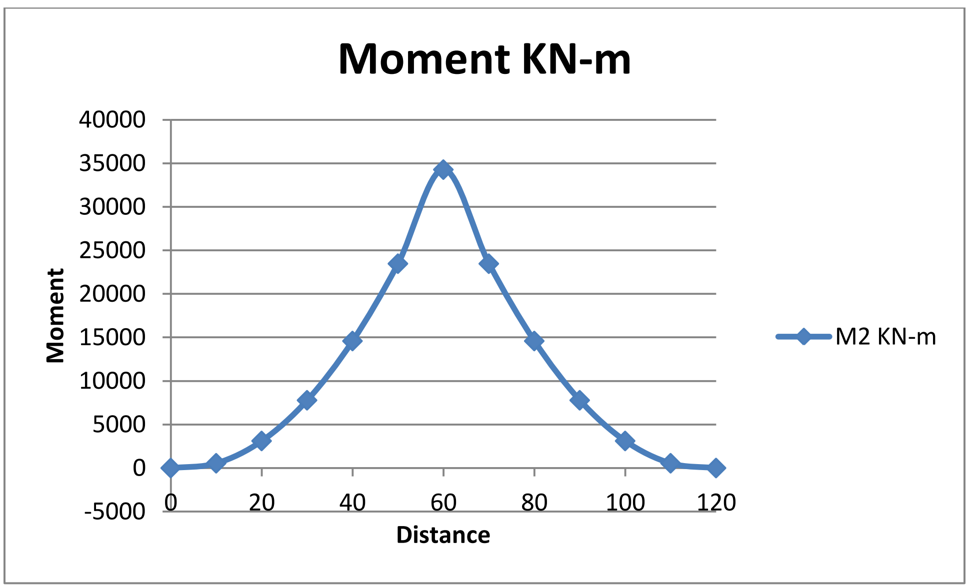


Figure 56: Moment for time history analysis for GM 3

Layout Line Distance	V3
m	KN
0	83.38
10	-409.22
20	-930.67
30	-1485.65
40	-2038.2
50	-2585.2
60	3046.84
70	2575.4
80	2038.2
90	1485.69
100	930.67
110	409.22
120	-83.38

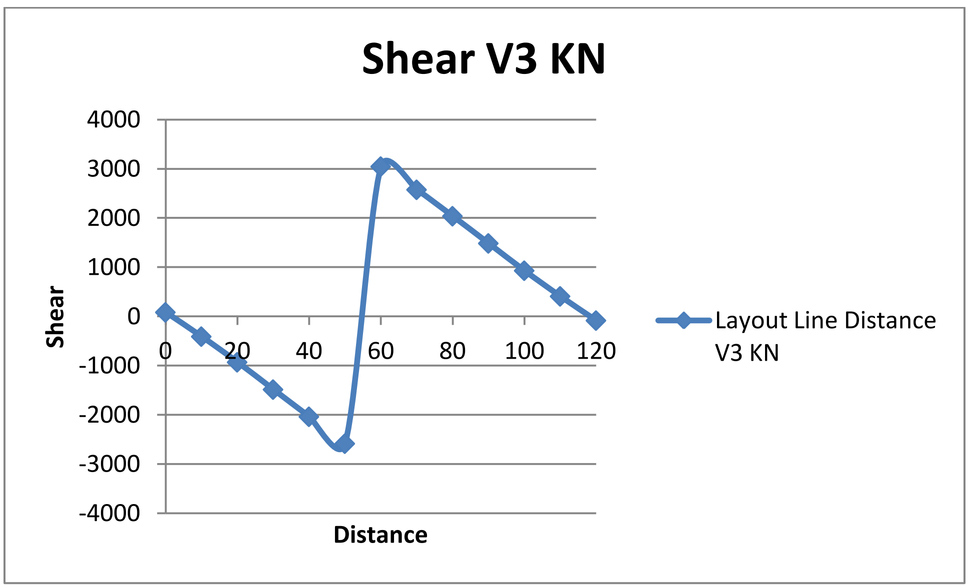
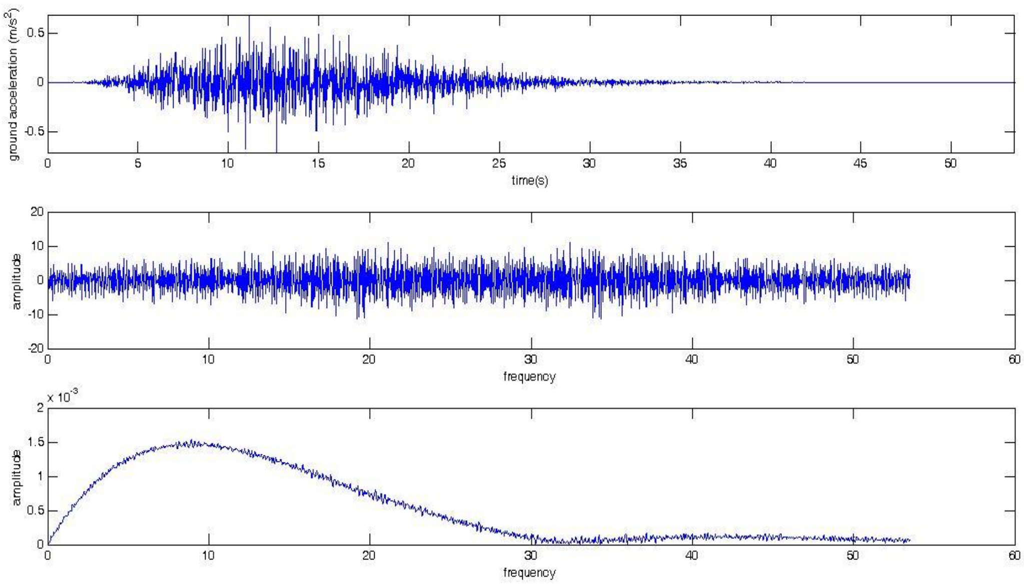
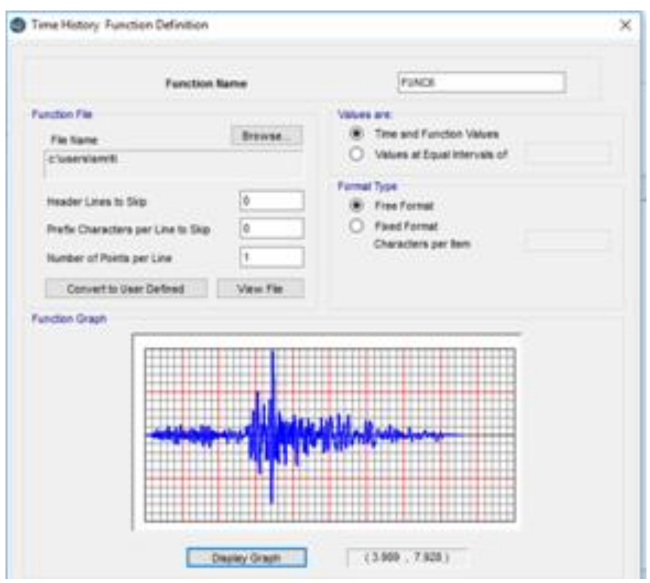


Figure 57: Shear force for time history analysis for GM 3

7.4 For ground motion 4





Layout Line Distance	M2
m	KN-m
0	34.1691
10	837.392
20	3672.8198
30	8622.387
40	15705.9349
50	24871.2416
60	31729.7066
70	21370.3403
80	12955.0328
90	6612.7128
100	2383.3708
110	222.5295
120	-16.6131

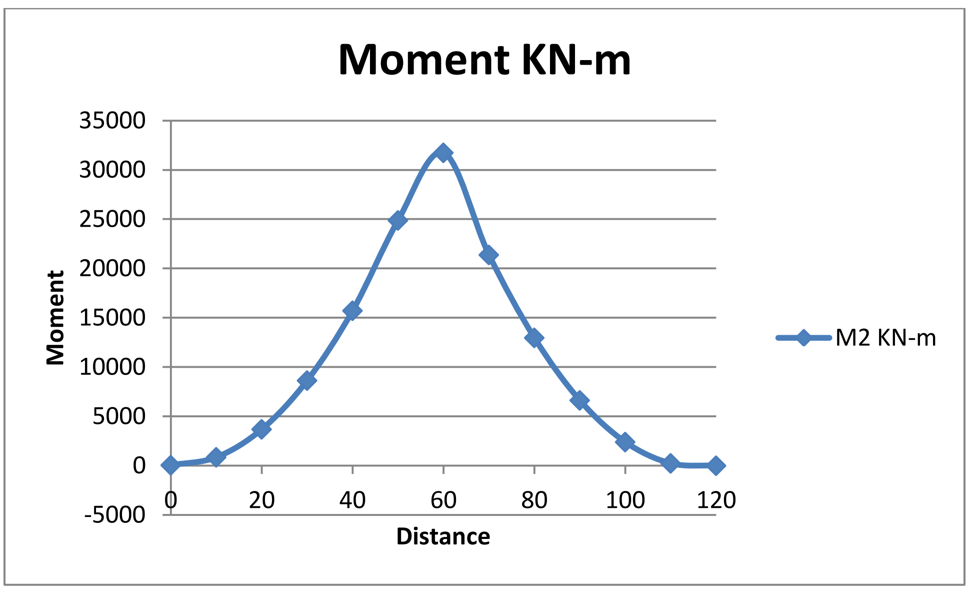


Figure 58: Moment for time history analysis for GM 4

Layout Line Distance	V3
m	KN
0	61.37
10	-384.13
20	-896.81
30	-1421.71
40	-1945.49
50	-2465.06
60	2820.35
70	2378.61
80	1884.61
90	1369.3
100	849.45
110	346.05
120	-101.65

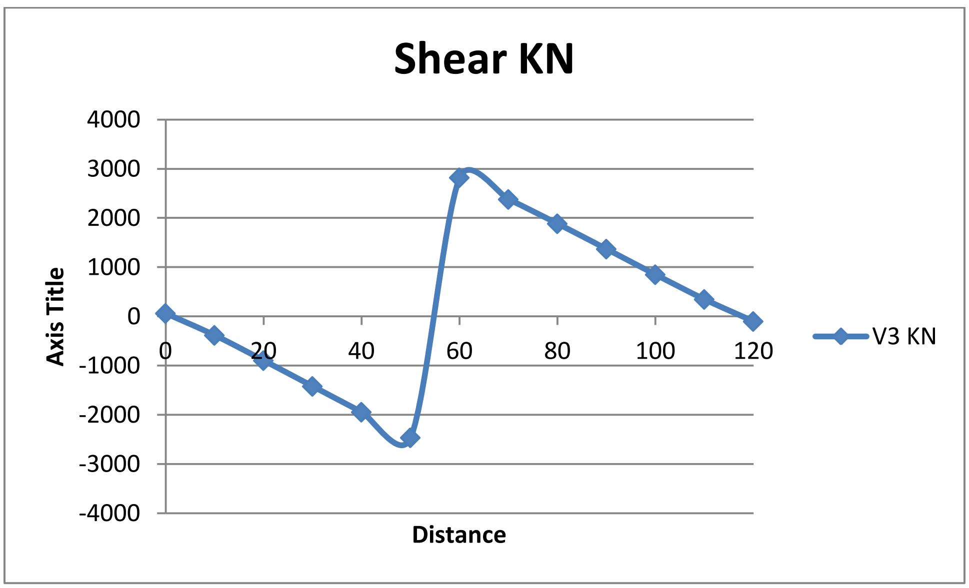


Figure 59: Shear force for time history analysis for GM 4

7.5 Discussion

Moments and shear force coming out from time history analysis for different input ground motions considering wave passage effect, incoherency effect and local site conditions are much higher than others.

Moments and Shear force for entire bridge considering different loads are:

Sr. No.	LOADS	MOMENT (kNm)	SHEAR FORCE (kN)
1.	Dead Load	27,404	2,434
2.	Live Load	8,648.4	937
3.	Moving Load	15,856	1,513.5
4.	Seismic load	21,399	1,902.13
5.	Response Spectrum Analysis	14,800	1,315.55
6.	Time History Analysis (GM1)	30,404	2,702
7.	Time History Analysis (GM2)	35,276	3,135.6
8.	Time History Analysis (GM3)	34,277	3,046.48
9.	Time History Analysis (GM4)	31,729	2,820.35

CONCLUSION

In this dissertation, we examined the response of bridge under differential support excitations employing response spectrum and time history analysis. Spatially varied ground motions due to wave passage, loss of coherency and local site conditions are taken into account. It is concluded the moments and shear force that is carried out by these effects are much higher and should be used for analysis in real bridges models by considering the effects of spatially varied ground motions.

Implementation of MSRS method in commercial software:

This study has demonstrated the accuracy of the MSRS method and its advantages for response analysis and time history analysis of multiply-supported structures subjected to spatially varying ground motions, particularly in the design stage where parametric analysis is often needed. For this method to be adopted in practice, it is necessary to implement it in commercial software like SAP2000, CSI Bridge etc.

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ANNEXURE

```
function [y,t] = seismSim(sigma,fn,zeta,f,T90,eps,tn)

% [y,t] = seismSim(sigma,fn,zeta,f,T90,eps,tn) generate one time series

% corresponding to acceleration record from a seismometer. The function

% requires 7 inputs, and gives 2 outputs. The time series is generated in

% two steps: First a stationnary process is created based on the Kanai-

% Tajimi spectrum, then an envelope function is used to transform this

% stationnary time series into a non-stationary record. For more

% information, see [1-3].

% [1] Lin, Y. K., & Yong, Y. (1987). Evolutionary Kanai-Tajimi earthquake

% models. Journal of engineering mechanics, 113(8), 1119-1137.

% [2] Rofooei, F. R., Mobarake, A., & Ahmadi, G. (2001).

% Generation of artificial earthquake records with a nonstationary

% KanaiTajimi model. Engineering Structures, 23(7), 827-837.

% [3] Guo, Y., & Kareem, A. (2016).

% System identification through nonstationary data using TimeFrequency Blind

% Source Separation. Journal of Sound and Vibration, 371, 110-131.

%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% INPUTS

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% sigma: [1 x 1 ]: standard deviation of the excitation.
```

```
% fn: [1 x 1 ]: dominant frequency of the earthquake excitation (Hz).

% zeta: [1 x 1 ]:  bandwidth of the earthquake excitation.

% f: [ 1 x M ]: frequency vector for the Kanai-tajimi spectrum.

% T90: [1 x 1 ]: value at 90 percent of the duration.

% eps: [1 x 1 ]: normalized duration time when ground motion achieves peak.

% tn: [1 x 1 ]: duration of ground motion.

%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% OUTPUTS

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% y: size: [ 1 x N ] : Simulated aceleration record

% t: size: [ 1 x N ] : time

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% EXAMPLE:

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% f = linspace(0,40,2048);

% zeta = 0.3;

% sigma = 0.9;

% fn =5;

% T90 = 0.3;

% eps = 0.4;

% tn = 30;
```

```
% [y,t] = seismSim(sigma,fn,zeta,f,T90,eps,tn);

% figure

% plot(t,y);axis tight

% xlabel('time(s)');

% ylabel('ground acceleration (m/s^2)')

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% see also fitKT.m

% Author: Etienne Cheynet - modified: 23/04/2016

%% Initialisation

w = 2*pi.*f;

fs = f(end);

dt = 1/fs;

f0= median(diff(f));

Nfreq = numel(f);

t = 0:dt:dt*(Nfreq-1);

%% Generation of the spectrum S

fn = fn *2.*pi; % transformation in rad;

s0 = 2*zeta*sigma.^2./(pi*fn.*(4*zeta.^2+1));

A = fn^4+(2.*zeta*fn.*w).^2;

B = (fn^2-w.^2).^2+(2.*zeta*fn.*w).^2;

S = s0.*A./B; % single sided PSD
```

```
%% Time series generation - Monte Carlo simulation

A = sqrt(2.*S.*f0);

B =cos(w'*t + 2*pi.*repmat(rand(Nfreq,1),[1,Nfreq]));

x = A*B; % stationary process

%% Envelop function E

b = -eps.*log(T90)./(1+eps.*(log(T90)-1));

c = b./eps;

a = (exp(1)./eps).^b;

E = a.*(t./tn).^b.*exp(-c.*t./tn);

%% Envelop multiplied with stationary process to get y

y = x.*E;

end


%% Groundmotion Simulation
clear;
clc;
%%**************************************
f = linspace(0,40,2048);
zeta = 0.3;
sigma = 0.9;
fn =5;
T90 = 0.3;
eps = 0.4;
tn = 30;
%%*****************************************

[y,t] = seismSim(sigma,fn,zeta,f,T90,eps,tn);
subplot(3,1,1)
plot(t,y);axis tight
xlabel('time(s)');
```

```
ylabel('ground acceleration (m/s^2)')
z=fft(y);
subplot(3,1,2)
plot(t,z)
xlabel('frequency');
ylabel('amplitude');

[b,a]=butter(2,.001,'low');
z1=filter(b,a,z);
subplot(3,1,3)
plot(t,abs(z1))
xlabel('frequency');
ylabel('amplitude');
```