A Preview of Structural Design Parameters for Flyovers Under Increasing Spatial Constraints

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Abstract:

Structural optimization considering two objectives simultaneously would generate a set of optimal solutions, which is called a Pareto set, instead of a unique optimal solution and thus may not satisfy the requirements of designers. This paper focuses on proposing a comprehensive criterion to weight each objective and thus convert multi-objective optimization problems to single-objective optimization problems.

In recent decades, the failure of bridges during service, as well as new construction has increased with an average of 129 bridges per year during the decade 2007–2017. The average age of the bridges is 34.53 years at failure during service against the prescribed design life of 100 years. The average age of failure of bridges in India is relatively high compared to failures in China (23.60 years) and much lower compared to failures in the USA (at least 51.70 years). Thus considering the local technical issues of Chhatrapati Sambhaji Nagar are considered and based on that a general framework is tried to prepare. In this paper, the factors affecting the design of the flyover are identified. Further they are classified as dependent and independent parameters and the bounds of independent parameters are identified based on the manual design of the flyover.

Keywords: *Structural optimization, optimal solutions, Multi-objective optimization, Pareto set.*

1. Introduction

The main objective of this paper is to comprehensively review the previous research on flyovers, provide a thorough analysis of the objectives and their temporal and spatial trends, and summarize the parameters and recommendations of future work.

The paper first introduces the significance of sustainability and efficiency in the AEC industry as well as the background of this review work. The selected articles are analyzed regarding the design objectives and their temporal and spatial trends.

The four major steps considered in the design process, including structural analysis and modeling, identification of dependent and independent parameters affecting the design of flyover identification and formulation of objective function, and computational tools and design platforms, are discussed in detail based on the collected articles. Finally, research gaps of the current works and potential directions of future works are proposed. This paper provides guidelines for future research on structural optimization in the field of civil engineering. Structural optimization is divided into four categories: Size, Shape, Topology, Multi-objective optimization.

2. Literature Review

There are three major research gaps, namely weighting criteria in multi-objective optimization, quantification of optimization objectives, and applicability of optimization algorithms.

First, structural optimization considering two objectives simultaneously would generate a set of optimal solutions, which is called Pareto set, instead of a unique optimal solution and thus may not satisfy the requirements of designers. Future work may focus on proposing a comprehensive criterion to weight each objective and thus convert multi-objective optimization problems to single objective optimization problems.

Second, mathematical quantifications must be found to represent the optimization objectives appropriately in order to conduct structural optimization. However, there has not been a standard method to evaluate the accuracy of objective quantifications yet, which is expected to be proposed in the future.

Third, the metaheuristic algorithms have limited applicability. In other words, the performance of a metaheuristic algorithm can be different for different optimization problems. Therefore, the future work may focus on categorizing the optimization problems according to their characteristics, and proposing a benchmarking system for each category of optimization problem including benchmark test problems and benchmark algorithms. Based on the benchmarking system, novel optimization algorithms could be developed to address a category of optimization problems with better performance rather than a specific optimization problem.

In recent decades, the failure of bridges during service, as well as new construction has increased with an average of 129 bridges per year during the decade 2007–2017. The average age of the bridges is 34.53 years at failure during service against the prescribed design life of 100 years. The average age of failure of bridges in India is relatively high compared to failures in China (23.60 years) and much lower compared to failures in the USA (at least 51.70 years).

3. Methodology

Establishment of a benchmarking system for optimization algorithm comparisons, in order to facilitate the development of new metaheuristic algorithms with higher applicability for structural optimization. To facilitate the comparisons of algorithms, the structural optimization problems could be classified into different categories based on the structure types, scales, or other characteristics. For each category of optimization problems, a few standardized structural optimization problems could be established as the benchmark test problems. Meanwhile, traditional metaheuristic algorithms with relatively better performance for each category of optimization problems could be used as the benchmark algorithms.

Afterward, the performance of any newly proposed algorithm can be verified by comparing it with the benchmark algorithms using the benchmark test problems for the respective category of the optimization problem. Based on the benchmarking system, it is expected that novel optimization algorithms could be developed to address a category of optimization problems with better performance rather than a specific optimization problem.

With the increasing attention on the environmental issue and sustainable development, reducing environmental impacts has become another significant objective of structural optimization because of the considerable amount of CO2 emissions in the civil engineering industry.

In addition, some research articles on structural optimization focus on improving certain structural performances such as mechanical behavior, aerodynamic performance, and dynamic seismic performance in order to adapt the structures to different environments. To achieve the above-mentioned objectives, many optimization methods have been proposed and developed. Recently, metaheuristic methods have become one of the most popular optimization methods in civil engineering structural optimization research because they are suitable for combinatorial optimization problems.

However, these metaheuristic methods also have some shortcomings such as high complexity and inadequacy for high-dimensional problems. Therefore, there have been increasing studies that focus on improving the performance of optimization methods, either to enhance the existing metaheuristic methods or to propose novel optimization methods. For example, Mortazavi proposed an auxiliary fuzzy decision mechanism to improve the performance of the interactive search algorithm (ISA) for structural size and topology optimization.

The combined algorithm, namely the fuzzy tuned interactive search algorithm (FTISA), achieves a lower computational cost and a higher solution accuracy. Degertekin proposed two improved harmony search algorithms (i.e., efficient harmony search algorithm and self-adaptive harmony search algorithm) for size optimization of truss structures. Based on the experimental results from several cases, the new algorithms are proved to have lower computational cost, higher convergence speed, and better optimization results than the traditional harmony search algorithm.

Furthermore, the explicit topology optimization method, namely the transformable triangular mesh (TTM) method, for structural topology optimization, is able to obtain the optimal solution more effectively compared with other state-of-the-art algorithms.

These above mentioned studies in the field of structural optimization presented the achievements and potential of structural optimization to improve the efficiency and sustainability of the civil engineering industry. However, although a substantial number of studies, as well as survey reports, were published in this domain, none of them achieved a comprehensive review of the research developments on structural optimization. Comprehensively review the state-of-the-art literature on structural optimization in the field of civil engineering, including the analysis of the optimization objectives and their temporal and spatial trends, analysis of the optimization processes with four major steps, and the discussions of research limitations and recommendations of future works.

3.1 Dependent Parameters

Dependent Parameters Sr. No.	Item	Type	Notation	Formula for Calculation	Value	Unit	Remark
1	Deck Thickness	Deck (Solid Slab Bridge) Design	D	0.04(S + 3000)	485	mm	Output
2	Live Load Equivalent Strip Width Interior strip width	Deck (Solid Slab Bridge) Design	E(interior)	250 + 0.42 * (L1 * W1)^0.5	4061.369832	mm	Calculation
3	Single-lane loaded	Deck (Solid Slab Bridge) Design		250 + 0.42 * (L1 * W1)^0.5	4061.369832	mm	Calculation
4	E(interior)	Deck (Solid Slab Bridge) Design		250 + [0.42 (L1*W1)^0.5]	4061.369832	mm	Calculation
5	Multilane loaded	Deck (Solid Slab Bridge) Design	NL	W / 3600	3	Nos.	Calculation

6	Dead Load: Slab	Deck (Solid Slab Bridge) Design	W(slab)	(Deck Thickness * Concrete Density * 9.81)	11.41884	kN. / sq. m.	Calculation
7	Future Wearing	Deck (Solid Slab Bridge) Design	W(fw)	(Barrier Width * Density of Wearing Surface * g)	1.6554375	kN. / sq. m.	Calculation
8	Half Span	Deck (Solid Slab Bridge) Design			4.575	Meters	Calculation
9	Live - Load Moments	Deck (Solid Slab Bridge) Design		W*L*L / 8	97.32740625	kN-m	Output
10	Moment due to the design truck	Deck (Solid Slab Bridge) Design	M(LL-Truck)	Calculate Moment at C (R * 0.5l) - (Load at A * 0.5)	316.59	kN-m	Output
11	Moment due to the Dead Load	Deck (Solid Slab Bridge) Design	M(DC)	W*L*L / 8	119.501729	kN-m	Output
12	Moment due to the Future Wearing Load	Deck (Solid Slab Bridge) Design	M(DW)	W*L*L / 8	17.32467076	kN-m	Output
13	Moment due to the design tandem	Deck (Solid Slab Bridge) Design	M (LL-Tandem)	Reaction at B * Distance	437.345406	kN-m	Output
14	Moment due to lane load	Deck (Solid Slab Bridge) Design	M (LL-Lane)	(W*l*l/8)	97.32740625	kN - m	Output
15	Determine Load Factors η	Deck (Solid Slab Bridge) Design	0.95	η * Total Moment	808.6996716	kN - m	Output
16	Total Moment	Deck (Solid Slab Bridge) Design		Moment due to the design truck + Moment due to the design tandem + Moment due to lane load	851.2628123	kN - m	Output
17	Load Combinations	Deck (Solid Slab Bridge) Design		0.95[1.25(MDC) + 1.50(MDW) + 1.75(M LL+IM)]	1055.489509	kN - m	Output

18	Ru	Deck (Solid Slab Bridge) Design		Mu/ (b*d*d)	3.618930013	Newton / Milli Meter	Calculation
19	m	Deck (Solid Slab Bridge) Design		fy / (0.85*fc)	17.64705882		Calculation
20	1/m	Deck (Solid Slab Bridge) Design			0.05666666667		Calculation
21	(2m*Ru) / fy	Deck (Solid Slab Bridge) Design			0.08403361345		Calculation
22	1 - ((2m*Ru) / fy)	Deck (Solid Slab Bridge) Design			0.9159663866		Calculation
23	(1 - ((2m*Ru) / fy))^0.5	Deck (Solid Slab Bridge) Design			0.9570613285		Calculation
24	1- ((1 - ((2m*Ru) / fy))^0.5)	Deck (Solid Slab Bridge) Design			0.04293867148		Calculation
25	ρ	Deck (Solid Slab Bridge) Design		(1/m)*(1-((2m*Ru)/fy)^0.5)	0.002433191384		Calculation
26	Required reinforced steel	Deck (Solid Slab Bridge) Design	As	ρbd	1180.097821	Milli Meter Square / Meter	Output
27	Maximum allowed spacing	Deck (Solid Slab Bridge) Design		(D + 20) / As	427.9306266	Milli Meters	Output
28	Spacing Provided	Deck (Solid Slab Bridge) Design			142.6435422	Milli Meters	Output
29	Determine Distribution Reinforcement	Deck (Solid Slab Bridge) Design		1750 / (L)^0.5	18.29479307	Percent	Output
30	Percentage of the main reinforcement for positive moment	Deck (Solid Slab Bridge) Design		1750 / (L1)^0.5	18.29479307	Percent	Calculation
31	Maximum allowed percent	Deck (Solid Slab Bridge) Design		From Code	50	Percent	Clause

32	As	Deck (Solid Slab Bridge) Design	As	(D+20) / Spacing Provided	3.540293463	Sq. Milli Meters / Milli Meter	Output
33	Required transverse reinforcement	Deck (Solid Slab Bridge) Design		As * Percentage of the main reinforcement for positive moment	0.6476893632	Sq. Milli Meters / Milli Meter	Output
34	Spacing Provided for transverse reinforcement	Deck (Solid Slab Bridge) Design		Maximum Spacing is 300 mm	300	Milli Meter	Output
35	Diameter of Transverse Reinforcement	Deck (Solid Slab Bridge) Design		((4As*Spacing)/Pi)^0.5	36.77114592	Milli Meter	Output
37	Effective length	Box-Girder Bridge Design	s	Centre to Centre Distance between the Centre Supports - Support Width	2695	Milli Meter	Calculation
50	Minimum reinforcement required	Box-Girder Bridge Design		0.03fc / fy	0.002	%	Calculation
51	Minimum As (Exterior Girder)	Box-Girder Bridge Design	Minimum As	Minimum reinforcement required * Ag (Exterior Girder)	2207.06	Milli Meter Square	Calculation
52	Provided As (Exterior Girder)	Box-Girder Bridge Design	Provided As	Minimum As (Exterior Girder) + 300	2507.06	Milli Meter Square	Output
53	Self weight of Concrete Slab	Box-Girder Bridge		Width * 0.2 * Concrete Density * g	31.07808	kN / m	Calculation
54	Dead Load	Box-Girder Bridge		Self weight + Barrier rail + Future wearing 75 mm AC overlay	60.67808	kN / m	Output
59	Interior web, the effective flange width	Box-Girder Bridge			2625	Milli Meter	Output
60	L (Effective) / 4	Box-Girder Bridge		L (Effective) / 4	8437.5	Milli Meter	Calculation
61	12ts + 0.5bf	Box-Girder Bridge		12ts + 0.5bf	2625	Milli Meter	Calculation

62	Exterior web, the effective flange width	Box-Girder Bridge			1312.5	Milli Meter	Output
63	L (Effective) / 8	Box-Girder Bridge		L (Effective) / 8	4218.75	Milli Meter	Calculation
64	6ts + 0.25bf	Box-Girder Bridge		6ts + 0.25bf	1312.5	Milli Meter	Calculation
65	Total effective flange width for the box girder	Box-Girder Bridge		(Interior web, the effective flange width * 0.5) + (Exterior web, the effective flange width) + (Interior web, the effective flange width)	5250	Milli Meter	Output
66	Area of Reinforcement Required	Box-Girder Bridge	As required	1% of the total cross-sectional area of the slab	2	Milli Meter Square / Milli Meter	Output
67	As (Top Layer)	Box-Girder Bridge	As (Top Layer)	(2/3) * Area of Reinforcement Required	1.333333333	Milli Meter Square / Milli Meter	Output
68	As (Bottom Layer)	Box-Girder Bridge	As (Bottom Layer)	(1/3) * Area of Reinforcement Required	0.6666666667	Milli Meter Square / Milli Meter	Output
69	Area for Steel Diameter of Top Layer	Box-Girder Bridge		(Pi / 4) * (Steel Diameter of Top Layer)^2	200.96	Milli Meters Square	Calculation
70	As (Top Layer)	Box-Girder Bridge			1.339733333	Milli Meter Square / Milli Meter	Calculation

71	Critical buckling stress	Pier Design	Fcr	(Ko*3.142*3.142*E)/(12*(1-(v*v))(b/nt)^2)	264.0882498	MPa	Output
72	Normalized Panel Slenderness Factor	Pier Design	Rp	(Fy/Fcr)^0.5	1.261101685	Unitless	Calculation
73	Buckling strength	Pier Design	Fu	Fu / Fy = 1 (Rp <= 0.5)	420	MPa	Calculation
74	Buckling strength	Pier Design	Fu	Fu / Fy = (1.5-Rp) (For 0.5<Rp<=1)	0.2388983148	MPa	Calculation
75	Buckling strength	Pier Design	Fu	Fu / Fy = (0.5/Rp*Rp) (For Rp>1)	0.3143907735	MPa	Calculation
76	Critical thickness	Pier Design	to	to = (b*Fy^0.5) / (162n)	18.97583475	Milli Meters	Output
77	Stiffness ratio	Pier Design	γi	γi = 11*I / bt^3	293.3333333	Uniteless	Calculation
78	Area	Pier Design	δi	Ai = δi * b * to	3339.746916	Milli Meter Square	Output
84	Abutment Support Width Design Support width (mm)	Abutment Design	N	N = (305 + 2.5L+10H) * (1+0.002 S.S)	1435.875	Milli Meters	Output
85	Soil lateral pressure by live-load surcharge	Abutment Design	qsc	Ka * γ * hsc	0.072	Kilo Pound per Square Foot	Calculation
86	Soil lateral pressure	Abutment Design	qe	Ka * γ * H	0.558	Kilo Pound per Square Foot	Calculation
87	Soil lateral pressure by seismic load	Abutment Design	qeq	Kae * γ * H	0.05952	Kilo Pound per Square Foot	Calculation
89	Maximum soil bearing pressure	Abutment Design	p(max)	(P/B)*(1+(6e/B))	80.88	MPa	Calculation
90	Minimum soil bearing pressure	Abutment Design	p(min)	(P/B)*(1-(6e/B))	39.12	MPa	Calculation
91	Resultant of vertical forces	Abutment Design	P		60	Kilo Pound per Square Foot	Calculation
92	Eccentricity of resultant of forces and the center of footing	Abutment Design	e	2B - (M/P)	0.058	Meters	Calculation

93	Area for Steel Diameter of Top Layer	Abutment Design		(Pi / 4) * (Steel Diameter of Top Layer)^2 * Number of Bars	565.2	Milli Meters Square	Output
94	Design speed in Meters / Second	Horizontal Curve	v	(Design Speed in km / hour) * (1000 / (3600))	30.55555 556	Meters / Second	Calculation
95	Superelevation in Number	Horizontal Curve	e	Superelevation in Percent / 100	0.06	Number	Calculation
96	Radius	Horizontal Curve	R	v*v /(g*(e + fs))	594.8279 659	Meters	Output
97	Pressure – Volume - Temperature Curve (PVT Curve) Elevation	Vertical Curve	y	y = ax*x + bx + c	995	Meters	Output
98	Elevation of the Point of Vertical Intersection (PVI)	Vertical Curve	y	y = bx + c	980	Meters	Output
99	dy / dx	Vertical Curve		dy/dx = 2ax + b	(2*0.0000 6)x - 0.004	Equation	Equation
100	Equate (dy / dx = 0) & Find **x**	Vertical Curve	x	From the above equation of (dy / dx)	333.3333 333	Meters	Output
101	Elevation of lowest point along the curve	Vertical Curve		Curve / Tangent Length + Point of Vertical Curve (PVC) + x in equation 7.10	933.3333 333	Meters	Output

3.2 Independent Parameters

Independent Parameters Sr. No.	Item	Type	Notation	Formula for Calculation	Value	Unit	Remark
1	Clear span length	General	S		9125	mm	Input
2	Total width	General	W		10700	mm	Input
3	Roadway Width	General	Wr		9640	mm	Input
4	Barrier Width	General			0.075	meters	Input
5	Concrete per linear meter of concrete barrier	General			0.24	meters	Input

6	Future wearing surface thickness	General	dw		75	mm	Input
7	Density of wearing surface	General	ρw		2250	kg/cu. m.	Input
8	Concrete density	General	ρc		2400	kg/cu. m.	Input
9	Concrete strength	General	fc		28	MPa	Input
10	Modulus of Elasticity of Concrete	General	Ec		26750	MPa	Input
11	Modulus of Elasticity of Steel	General	Es		200000	MPa	Input
12	Characteristic Strength of Steel	General	fy		420	MPa	Input
13	Lesser of actual span length and 18,000 mm	Deck (Solid Slab Bridge) Design	L1		9150	mm	Input
14	Lesser of actual width or 9000 mm for single lane loading or 18,000 mm for multilane loading	Deck (Solid Slab Bridge) Design	W1		9000	mm	Input
15	W/NL	Deck (Solid Slab Bridge) Design		W/NL	4024.68	mm	Input
16	E(interior)	Deck (Solid Slab Bridge) Design		2100 + [0.21 (L1*W1)^0.5]	4024.6817 92	mm	Input
17	Live Load	Deck (Solid Slab Bridge) Design	W(L)		9.3	kN / m	Input
18	Concrete barrier	Deck (Solid Slab Bridge) Design	W(barrier)	(Concrete per linear meter of concrete barrier * Concrete Density * g)	4.5	kN. / sq. m.	Input
19	Point Load at A	Deck (Solid Slab Bridge) Design			145	kilo Newton	Input
20	Point Load at C	Deck (Solid Slab Bridge) Design			145	kilo Newton	Input
21	Point Load at B	Deck (Solid Slab Bridge) Design			35	kilo Newton	Input
22	Total Span	Deck (Solid Slab Bridge) Design			9.15	Meters	Input

23	Reaction at A	Deck (Solid Slab Bridge) Design			214.2	kilo Newton	Input
24	Reaction at A	Deck (Solid Slab Bridge) Design			110.8	kilo Newton	Input
25	Reaction at B	Deck (Solid Slab Bridge) Design			95.58	kilo Newton	Input
26	Distance	Deck (Solid Slab Bridge) Design			4.5757	Milli Meter	Input
27	Load for lane load	Deck (Solid Slab Bridge) Design			9.3	kilo Newton	Input
28	Reinforcement Design Diameter of Bar	Deck (Solid Slab Bridge) Design			25	Milli Meter	Input
29	Span length	Box-Girder Bridge Design	L1		24390	Milli Meter	Input
30	Span length	Box-Girder Bridge Design	L2		30480	Milli Meter	Input
31	Total superstructure width	Box-Girder Bridge Design	W		10800	Milli Meter	Input
32	Roadway width	Box-Girder Bridge Design	W(R)		9730	Milli Meter	Input
33	Thickness of future wearing surface.	Box-Girder Bridge Design	dw		75	Milli Meter	Input
34	Overall Structural Thickness	Box-Girder Bridge Design	h		1680	Milli Meter	Input
35	Support Width	Box-Girder Bridge Design			205	Milli Meter	Input
36	Centre to Centre Distance between the Centre Supports	Box-Girder Bridge Design			2900	Milli Meter	Input
37	Ag (Exterior Girder)	Box-Girder Bridge Design	Ag		1103530	Milli Meter Square	Input
38	Number of Span	Box-Girder Bridge			2	Number	Input
39	Span Length	Box-Girder Bridge			45	Meters	Input

40	Width of Super Structure	Box-Girder Bridge			13.2	Meters	Input
41	Characteristic Strength of Steel	Box-Girder Bridge	fy		345	MPa	Input
42	Characteristic Strength of Concrete	Box-Girder Bridge	fc		30	MPa	Input
43	Modulus of Elasticity of Concrete	Box-Girder Bridge	Ec		22400	MPa	Input
44	Modular Ratio	Box-Girder Bridge	n		8	Unitless	Input
45	Barrier rail	Box-Girder Bridge			5.7	kN / m	Input
46	Haunch	Box-Girder Bridge			3.5	kN / m	Input
47	Girder (steel-box), cross frame, diaphragm, and stiffener	Box-Girder Bridge			9.8	kN / m	Input
48	Future wearing 75 mm AC overlay	Box-Girder Bridge			10.6	kN / m	Input
49	Concrete slabs deck thickness	Box-Girder Bridge			200	Milli Meter	Input
50	Width for the box girder	Box-Girder Bridge			6.6	Meters	Input
51	L (Effective)	Box-Girder Bridge			33750	Milli Meter	Input
52	Thickness	Box-Girder Bridge	ts		200	Milli Meter	Input
53	Width of Flange	Box-Girder Bridge	bf		450	Milli Meter	Input
54	Span Length	Box-Girder Bridge			3750	Milli Meter	Input
55	L (Effective)	Box-Girder Bridge			33750	Milli Meter	Input
56	Thickness	Box-Girder Bridge	ts		200	Milli Meter	Input
57	Width of Flange	Box-Girder Bridge	bf		450	Milli Meter	Input
58	Width of Overhang	Box-Girder Bridge			1500	Milli Meter	Input
59	Spacing	Box-Girder Bridge			150	Milli Meters	Input
60	Steel Diameter of Top Layer	Box-Girder Bridge			16	Milli Meters	Input
61	Stiffened plate width	Pier Design	b		0.6	Milli Meter Square	Input
62	Stiffened plate Thickness	Pier Design	t		0.5	Milli Meter Square	Input
63	Number of panel spaces in the plate	Pier Design	n		4	Number	Input
64	Factor taking into account the boundary conditions.	Pier Design	Ko		4	Unitless	Input
65	Poisson's ratio for steel	Pier Design	v		0.3	Uniteless	Input
66	Buckling strength	Pier Design	Fu	Fu cannot be less than 0.25	0.25	MPa	Input

67	Factor of Safety	Pier Design			1.7	Uniteless	Input
68	Moment of inertia	Pier Design	I		2	m^4	Input
69	Superstructure dead load	Abutment Design	P(DL)		7251	kilo Newton	Input
70	HS20 live load	Abutment Design	P(HS)		1824	kilo Newton	Input
71	1.15 P-load + 1.0 HS load	Abutment Design	Pp		1245	kilo Newton	Input
72	Longitudinal live load	Abutment Design	F		1103	kilo Newton	Input
73	Longitudinal seismic load (bearing pad capacity)	Abutment Design	Feq		1450	kilo Newton	Input
74	Transverse seismic load	Abutment Design			5520	kilo Newton	Input
75	Bridge temperature displacement	Abutment Design			75	Milli Meter	Input
76	Bridge seismic displacement	Abutment Design			165	Milli Meter	Input
77	Live-load surcharge	Abutment Design			0.61	Meters	Input
78	Unit weight of backfill soil	Abutment Design			1922	kg / cu. m.	Input
79	Allowable soil bearing pressure	Abutment Design			0.19	MPa	Input
80	Soil lateral pressure coefficient	Abutment Design	Ka		0.3	Unitless	Input
81	Angle for Friction coefficient in Degrees	Abutment Design			33	Degrees	Input
82	Soil liquefaction potential	Abutment Design			Very Low	Unitless	Input
83	Ground acceleration	Abutment Design			0.3g	Meters / second	Input
84	Width of abutment	Abutment Design			0.305	Meters	Input
85	Reinforcement yield stress	Abutment Design	fy		414	MPa	Input
86	Concrete strength	Abutment Design	fc		22.41	MPa	Input
87	Length (m) of the bridge deck to the adjacent expansion joint, or to the end of bridge deck; for single-span bridges L equals the length of the bridge deck	Abutment Design	L		65	Meters	Input
88	Angle of skew at abutment in degrees	Abutment Design	S		5	Degrees	Input

89	Average height (m) of columns or piers supporting the bridge deck from the abutment to the adjacent expansion joint, or to the end of the bridge deck; H = 0 for simple span bridges	Abutment Design	H		90	Meters	Input
90	Unit weight of soil	Abutment Design	γ		0.12	kN / cu. m.	Input
91	Height of live-load surcharge	Abutment Design	hsc		2	Meters	Input
92	Height	Abutment Design	H		15.5	Meters	Input
93	Coefficient of active earth pressure	Abutment Design	Kae		0.032	Unitless	Input
95	Abutment footing width	Abutment Design	B		1	Meters	Input
96	Total moment to point A	Abutment Design	M		116.52	Kilo Feet	Input
97	Steel Diameter	Abutment Design			12	Milli Meters	Input
98	Effective Cover	Abutment Design			50	Milli Meters	Input
99	Number of Bars	Abutment Design			5	Nos	Input
100	Design Speed in km / hour	Horizontal Curve	v		110	km / hour	Input
101	Superelevation in Percent	Horizontal Curve	e		6	Percent	Input
102	Coefficient of side friction	Horizontal Curve	fs		0.1	No Unit	Input
103	Curve / Tangent Length	Vertical Curve	x		500	Meters	Input
104	Point of Vertical Curve (PVC)	Vertical Curve			100	Meters	Input
105	Elevation	Vertical Curve	c		1000	Meters	Input
106	Initial Grade	Vertical Curve	b		-4	Percent	Input
107	Final Grade	Vertical Curve			2	Percent	Input
108	a	Vertical Curve	a		0.00006	No Unit	Input
109	Selecting the type of bearing	Bearings		Elastomeric Pads, Pot Bearings, Spherical Bearings		Text	Input

3.3 Independent Parameters and Their Bounds

Independent Parameters Sr. No.	Item	Type	Notation	Minimum	Maximum	Remark
1	Clear span length	General	S	9000	30000	Continuous
2	Total width	General	W	9000	11500	Continuous
3	Roadway Width	General	Wr	2000	8000	Continuous
4	Barrier Width	General		0.3	0.5	Continuous
5	Concrete per linear meter of concrete barrier	General		0.16	3.84	Continuous
6	Future wearing surface thickness	General	dw	25	80	Continuous
7	Density of wearing surface	General	ρw	1190	2500	Continuous
8	Concrete density	General	ρc	2300	2700	Continuous
9	Concrete strength	General	fc	15	55	Continuous
10	Modulus of Elasticity of Concrete	General	Ec	18203.02173	37080.99244	Continuous
11	Modulus of Elasticity of Steel	General	Es	200000	200000	Continuous
12	Characteristic Strength of Steel	General	fy	250	2693	Continuous
13	Lesser of actual span length and 18,000 mm	Deck (Solid Slab Bridge) Design	L1	1000	18000	Continuous
14	Lesser of actual width or 9000 mm for single lane loading or 18,000 mm for multilane loading	Deck (Solid Slab Bridge) Design	W1	9000	18000	Continuous
15	W/NL	Deck (Solid Slab Bridge) Design		1000	5000	Continuous
16	E(interior)	Deck (Solid Slab Bridge) Design		1000	5000	Continuous
17	Live Load	Deck (Solid Slab Bridge) Design	W(L)	9	115	Continuous

19	Point Load at A	Deck (Solid Slab Bridge) Design		1	1000	Continuous
20	Point Load at C	Deck (Solid Slab Bridge) Design		1	1000	Continuous
21	Point Load at B	Deck (Solid Slab Bridge) Design		1	1000	Continuous
22	Total Span	Deck (Solid Slab Bridge) Design		8	30	Continuous
23	Reaction at A	Deck (Solid Slab Bridge) Design		1	1000	Continuous
24	Reaction at A	Deck (Solid Slab Bridge) Design		1	1000	Continuous
25	Reaction at B	Deck (Solid Slab Bridge) Design		1	1000	Continuous
26	Distance	Deck (Solid Slab Bridge) Design		0	30	Continuous
27	Load for lane load	Deck (Solid Slab Bridge) Design		9.3	21.8	Continuous
28	Reinforcement Design Diameter of Bar	Deck (Solid Slab Bridge) Design		8	32	Discrete
29	Span length	Box-Girder Bridge Design	L1	8	30	Continuous

30	Span length	Box-Girder Bridge Design	L2	8	30	Continuous
31	Total superstructure width	Box-Girder Bridge Design	W	8000	15000	Continuous
32	Roadway width	Box-Girder Bridge Design	W(R)	3000	60000	Continuous
33	Thickness of future wearing surface.	Box-Girder Bridge Design	dw	70	210	Continuous
34	Thickness of future wearing surface.	Box-Girder Bridge Design	h	1000	2000	Continuous
35	Support Width	Box-Girder Bridge Design		100	500	Continuous
36	Centre to Centre Distance between the Centre Supports	Box-Girder Bridge Design		2000	35000	Continuous
37	Ag (Exterior Girder)	Box-Girder Bridge Design	Ag	100000	2000000	Continuous
61	Stiffened plate width	Pier Design	b	0.5	2	Continuous
62	Stiffened plate Thickness	Pier Design	t	10	50	Continuous
63	Number of panel spaces in the plate	Pier Design	n	2	10	Continuous
64	Factor taking into account the boundary conditions.	Pier Design	Ko	0	10	Continuous
65	Poisson’s ratio for steel	Pier Design	v	0.28	0.3	Discrete
66	Buckling strength	Pier Design	Fu	0.25	0.4	Continuous
67	Factor of Safety	Pier Design		1	2	Continuous
68	Moment of inertia	Pier Design	I	1	10	Continuous
100	Design Speed in km / hour	Horizontal Curve	v	15	115	Continuous
101	Superelevation in Percent	Horizontal Curve	e	2	6	Continuous
102	Coefficient of side friction	Horizontal Curve	fs	0.08	0.15	Continuous

103	Curve / Tangent Length	Vertical Curve	x	10	1000	Continuous
104	Point of Vertical Curve (PVC)	Vertical Curve		10	500	Continuous
105	Elevation	Vertical Curve	c	50	1500	Continuous
106	Initial Grade	Vertical Curve	b	-4	3	Continuous
107	Final Grade	Vertical Curve		1	3	Continuous
108	a	Vertical Curve	a	0.00001	0.00006	Continuous
109	Selecting the type of bearing	Bearings		1	3	Discrete

4. Objectives

- To identify different parameters affecting the design of the flyover.
- Formulation of optimization problem.
- Create the design for case study from the manual design of the flyover.

5. Conclusion

The current paper identifies the parameters influencing the design of flyovers. From the parameters identified the designer can optimize the independent parameters which indirectly influence the Length, Cost and Environmental Impact Assessment of the structure. Total two hundred and thirteen parameters are identified out of which 109 are independent and 104 are dependent which can be further used for designing the framework for a flyover.

6. Limitations and Future Work

Based on the parameters identified, the development of a framework for the design of the flyover can be done using a multi-objective optimization technique for a rapidly growing township.

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8. References

[1] L. Mei and Q. Wang, “Structural Optimization in Civil Engineering: A Literature Review,” Buildings, vol. 11, no. 2, Art. no. 2, Feb. 2021, doi: 10.3390/buildings11020066.

[2] J. López, C. Anitescu, N. Valizadeh, T. Rabczuk, and N. Alajlan, “Structural shape optimization using Bézier triangles and a CAD-compatible boundary representation,” *Engineering with Computers*, vol. 36, no. 4, pp. 1657–1672, Oct. 2020, doi: 10.1007/s00366-019-00788-z.

[5] V. S. Papapetrou, A. Y. Tamijani, J. Brown, and D. Kim, “Design Optimization of Hybrid FRP/RC Bridge,” *Appl Compos Mater*, vol. 26, no. 1, pp. 249–270, Feb. 2019, doi: 10.1007/s10443-018-9691-3.

[6] R. J. Aguilar, K. Movassaghi, J. A. Brewer, and J. C. Porter, “Computerized optimization of bridge structures,” *Computers & Structures*, vol. 3, no. 3, pp. 429–442, May 1973, doi: 10.1016/0045-7949(73)90089-8.

[7] V. Penadés-Plà, T. García-Segura, and V. Yepes, “Robust Design Optimization for Low-Cost Concrete Box-Girder Bridge,” *Mathematics*, vol. 8, no. 3, Art. no. 3, Mar. 2020, doi: 10.3390/math8030398.

[8] L. F. Wang and A. P. Tang, “Collaborative Optimization Design of Bridge System Using Two Decomposition Methods Considering Aseismic Requirements,” p. 9.

[9] F. Riaz, A. Riaz, K. Alam, and A. S. Abid, “Design Optimization of Modular Bridge Structure,” *Applied Mechanics and Materials*, vol. 328, pp. 970–974, 2013, doi: 10.4028/www.scientific.net/AMM.328.970.

[10] B. Briseghella, L. Fenu, C. Lan, E. Mazzarolo, and T. Zordan, “Application of Topological Optimization to Bridge Design,” *Journal of Bridge Engineering*, vol. 18, no. 8, pp. 790–800, Aug. 2013, doi: 10.1061/(ASCE)BE.1943-5592.0000416.

[11] F. D. Chitty, C. J. Freeman, and D. B. Garber, “Joint Design Optimization for Accelerated Construction of Slab Beam Bridges,” *Journal of Bridge Engineering*, vol. 25, no. 7, p. 04020029, Jul. 2020, doi: 10.1061/(ASCE)BE.1943-5592.0001561.

[12] H. Xin, A. Mosallam, J. A. F. O. Correia, Y. Liu, J. He, and Y. Sun, “Material-structure integrated design optimization of GFRP bridge deck on steel girder,” *Structures*, vol. 27, pp. 1222–1230, Oct. 2020, doi: 10.1016/j.istruc.2020.07.008.

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