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Finite Element Modelling and Link Element Analysis for Load Behaviour in Elastomeric Bearings: An Approach to Satisfy Design Check

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Abstract: The focus of this study is on the finite element modelling (FEM) and link element analysis of elastomeric bearings to evaluate load behaviour and ensure compliance with design standards. A detailed FEM was developed, incorporating material properties and boundary conditions to simulate the load transfer mechanisms that were provided through link element analysis. The results were validated against design codes and input data from analysis software data, confirming the model's accuracy. A reliable method for optimizing elastomeric bearing design, improving structural safety, and satisfying critical design checks has presented. Total 10 Models taken with its variations and design checks applied over the same with the conclusion of whether it would be suitable or not aiming to improve design practices and address the challenges of modern bridge engineering. Keywords: Link element, Elastomer, Steel laminates, Bridge, 70R loading, Data validation.

I. INTRODUCTION

Bridge engineering is recognized as a crucial field in infrastructure development, ensuring the safe and efficient movement of people and goods across natural and man-made obstacles. Bridges are subjected to various dynamic loads, including vehicular traffic, wind forces, thermal expansion, and seismic activity. To manage these forces and maintain structural integrity, the use of specialized components, such as bearings, is required. Bearings are employed to allow controlled movement between the bridge superstructure and substructure, while the distribution of loads is managed, minimizing stress on critical elements.

Elastomeric bearings, which are widely used, are designed to handle vertical loads while permitting horizontal movement and rotation. These bearings are composed of alternating layers of rubber (elastomer) and steel shims, allowing vibrations to be absorbed, effects of temperature changes to be mitigated, and deflections due to seismic and wind forces to be accommodated. Their flexible nature provides a cost-effective and low-maintenance solution for various bridge types, including highway and railway bridges.

II. APPLICATION OF ELASTOMERIC BEARING

The application of elastomeric bearings in bridge engineering ensures that smoother load distribution is achieved, the lifespan of the structure is prolonged, and the overall safety and durability of the bridge are enhanced. However, careful consideration of material properties, load conditions, and deformation behaviour has required in their design, making finite element modeling (FEM) an essential tool for analysing and optimizing their performance. By predicting how elastomeric bearings respond to various load scenarios, critical design checks can be satisfied, contributing to the long-term reliability of bridges.

In the figure below, the bridge firstly was supported only on the girder merged to the pier. Then the Elastomeric bearing applied to ROB after re-refection of actual shear forces, bending moment and torsional moment



Fig. 1: Elastomeric bearing used in ROB

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III. RESEARCH OBJECTIVES

On keeping in mind the above problem statement outlined for new research work for elastomeric bearing are given below :-

- 1) To check behavior in the analysis, it is recommended to take different Model cases considering the thickness of each layer of bearing as constant throughout all model cases and changing only bearing pad dimensions as variable.
- 2) For accuracy in analysis, it has recommended to make the variants of each of the model cases
- 3) To simulate precisely, it has recommended to use the FEM analysis over each variants.
- 4) Loading used over the bridge should be highest as per IRC 6:2017.
- 5) For the stability in the simulation, it has suggested that to conduct different design checks for the values obtained as per the output parameters decided.
- 6) At last, in the research, the most stable cases list after passing the design tests can be taken into account that provides the recommendations that will made a feasible construction reference.

IV. 3D MODELLING OF THE STRUCTURE

Comprehensive input data and its descriptions about the model given below. The input data used for creation of elastomeric bearing using link element using general data and loading data have shown below:-

Constraint	Data used for all cases
IRC loading	70R
Vehicle width	2.79 m
Dead load	Self-Weight

Table 1: Loading data used for all model cases

Constraint	Data used for all cases								
Deck Span length	12m								
Deck width	5m								
Deck Span thickness	300mm								
Transverse girder properties	500 mm x 300 mm								
Number of plate meshing	10 x 10								
	Beam selected = tapered I sec	ction							
	Property used = Steel section	on							
Longitudinal girder properties	F1 (Depth of Section at Start Node) F2 (Thickness of Web) F3 (Depth of Section at Start Node) F3 (Depth of Section at End Node) F4 (Width of Top Flange) F5 (Thickness of Top Flange) F6 (Width of Bottom Flange) F7 (Thickness of Bottom Flange)	0.6 m 0.012 m 0.6 m 0.21 m 0.0208 m 0.220 m 0.0208 m							
Concrete & Rebar grade	M30 & FE 500								
Shear Modulus (G)	0.9 N/sq. mm (IRC 83, Table 1)								
Modulus of Elasticity of Elastomer (E)	617263 KG/sq. m (from Ref. paper 1)								

Table 2: General input data used for all model cases





Fig. 2: Plan view of bridge

Models framed for analysis	Abbreviation	Subsequent	Variant		
	110010 (100101	variant	Configuration		
		EB1A	1E, 2O, 2S		
Bridge deck supported over laminated elastomeric	Model 1	EB1B	2E, 2O, 3S		
bearing with effective area of 160mm x 250mm	NIOUEI I	EB1C	3E, 2O, 4S		
		EB1D	4E, 2O, 5S		
		EB2A	1E, 2O, 2S		
Bridge deck supported over laminated elastomeric	Model 2	EB2B	2E, 2O, 3S		
bearing with effective area of 160mm x 320mm	WIOdel 2	EB2C	3E, 2O, 4S		
		EB2D	4E, 2O, 5S		
		EB3A	1E, 2O, 2S		
Bridge deck supported over laminated elastomeric	Model 2	EB3B	2E, 2O, 3S		
bearing with effective area of 200mm x 320mm	WIDdel 5	EB3C	3E, 2O, 4S		
		EB3D	4E, 2O, 5S		
		EB4A	1E, 2O, 2S		
Bridge deck supported over laminated elastomeric	Model 4	EB4B	2E, 2O, 3S		
bearing with effective area of 200mm x 400mm	Wodel 4	EB4C	3E, 2O, 4S		
		EB4D	4E, 2O, 5S		
		EB5A	1E, 2O, 2S		
Bridge deck supported over laminated elastomeric	Model 5	EB5B	2E, 2O, 3S		
bearing with effective area of 250mm x 400mm	Widdel 3	EB5C	3E, 2O, 4S		
		EB5D	4E, 2O, 5S		
		EB6A	1E, 2O, 2S		
Bridge deck supported over laminated elastomeric	Model 6	EB6B	2E, 2O, 3S		
bearing with effective area of 250mm x 500mm	WIDdel 0	EB6C	3E, 2O, 4S		
		EB6D	4E, 2O, 5S		
		EB7A	1E, 2O, 2S		
Duidge deals supported even leminated electomenia		EB7B	2E, 2O, 3S		
bridge deck supported over familiated elastometric	Model 7	EB7C	3E, 2O, 4S		
ocaring with checuve area of 520min x 500min		EB7D	4E, 2O, 5S		
		EB7E	5E, 2O, 6S		
Bridge deck supported over laminated elastomeric	Model 8	EB8A	1E, 2O, 2S		

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bearing with effective area of 320mm x 630mm		EB8B	2E, 2O, 3S
		EB8C	3E, 2O, 4S
		EB8D	4E, 2O, 5S
		EB8E	5E, 2O, 6S
		EB9A	1E, 2O, 2S
Bridge deck supported over leminated electomeric		EB9B	2E, 2O, 3S
bearing with effective area of 320mm x 630mm	Model 9	EB9C	3E, 2O, 4S
bearing with effective area of 520min x 050min		EB9D	4E, 2O, 5S
		EB9E	5E, 2O, 6S
		EB10A	1E, 2O, 2S
		EB10B	2E, 2O, 3S
Bridge deck supported over laminated elastomeric	Model 10	EB10C	3E, 2O, 4S
bearing with effective area of 400mm x 800mm	Model 10	EB10D	4E, 2O, 5S
		EB10E	5E, 2O, 6S
		EB10F	6E, 2O, 7S

Here,	
EB = Elastomeric Bearing,	
9A = Variant A for model number 9	2O = 2 Outer Elastomeric layer
1E = 1 Elastomeric sheet layer	2S = 2 Steel laminate layer

V. DESIGN CHECK PROCEDURE OF BEARING AS PER IRC 83

The procedure followed to observe whether the bearing created by link element has safe to resist from failure mentioned below:-

Laminated Elastomeric Bearing Design





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Bearing stress	αm			N/sq	. mm a	nswer				
Taking different thickness of individual layers							•			
(a) Elastomeric Layers	hi				x		mm	From IRC 8	33, 916.3.3, pi	no. 10
(b) Thickness of outer layer	he				x		mm	From IRC 8	33, 916.3.3, pi	no. 10
(c) Thickness of steel laminates	hs				ĸ		mm	From IRC 8	33, 916.3.3, pi	no. 10
Side covering	C			m	m			From IRC 8	33, 916.2.2, pi	no. 9
Overall Thickness	ho			m	im a	nswer				
Shape factor										
It should be greater than 6 and less than 12	s					nswer				
	Valu	ie	>	Va	lue	<	Value			
	ł	Hence	ok safe !!	From	IRC 83	, 916.3.	3, pno.	10		
(II) Shear strain due to creep, shrinkage and	temperat	ture				From		02 016 2	1 222 10	
		ycsi				From	n IRC	83, 910.3	4, pno. 10	
(III) Shear strain due to transational momen	t									
		γd						answer		
				Valu	e		<	0.7		
			Hence o	k safe !	!	From	n IRC	83, 916.3	4, pno. 10	
iv) Permissible rotation		am						From IS	0 92 916 2	5 000 1
		α him	nav			radi	4. mm ans	answer		, prio. 1
		ß				N/s/	a			
o of internal lavers		n				nos	4	answer		
Permissible rotation		α _d		Valu	e	1103.	>	Value		
		C.C	Hence o	k safe l		From	r n IRC	83-2018	5136 nm	o 17
			include o	noure i			ii iiie	03.2010,	5.1.5.0, pm	5.17
Shear strain due to friction										
	vf									
			Value		>	Va	lue			
		Hence	e ok safe !!	Fr	om IR(83. 91	6.3.6.	pno, 11		
			and							
	Val	ue	>		Value		> v	/alue		
	• • • •	Hence	e ok safe !!	Fr	om IR(- 83 91	633	nno 10		
					on na	5 05, 51	.0.0.0,	pno. 10		
Total shear stress					,					
Due to compression				N	/sq. m ,	m				
Due to horizontal deformation				N	/sq. m ,	m				
Due to rotation				N	/sq. m	m				
Total shear stress				N	/sq. m	m				
			Value	-	<	Va	lue a	and < 7 , F	rom IRC 83:	2018, 5.1.3
		Hence	e ok sate !!	FI	om IR	083, 91	.6.3.7,	pno. 11		
c	heck fo	r Be	aring (P	ass/Fa	nil)					
(I) Selection of bearing pad dimen	sions				v	/alue		<	Value	
(II) Shear strain due to creep, shrin	kage and	temp	erature		V	/alue		<	Value	
(III) Shear strain due to transationa	al momen	t			V	alue		<	Value	
(IV) Permissible rotation					v v	alue alue		>	Value	
(V) Snear strain due to friction (VI) Total shear stress					v	aiue /alue		~	Value	
(vi) rotar sited stress						ande			value	
Fig. 3: Samp	ole of dif	feren	t checks	condu	cted f	for m	odel			

VI. RESULTS AND DISCUSSION

Though our result analysis consists Total 10 distinct model cases and each having different variants of elastomeric bearing cases. The result analysis approach allowed us to observe a range of outcomes for each case within the structure since different variants shows different behaviour under 70R loading. As a result of this comparative analysis, we obtained subsequent findings for the mentioned cases provided below:-



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С

D

Area of 200 x 400 is restricted for 70R loading used in

2 outer layers

4 steel laminates

4 elastomeric laver

2 outer layers

5 steel laminates

Fail

Fail

			1 a	ble 4: Result a	narysis	various models with notes										
		Results for M	el 1				Results for Model 2									
On anal	yzing Mo	odel EB1A, EB1	IB,	EB1C and E	B1D al	11 6	C	On analyzing Model EB2A, EB2B, EB2C and EB2D all 6								
different checks for elastomeric bearing by IRC 83 hav								different checks for elastomeric bearing by IRC 83 have								
performed and are not within the limit and hence failed.							р	erforme	ed and a	re not within the	lin	nit and hence fa	uiled.			
Model (Under 70R Loading)	Area	Thickness figure	Th	ickness configuration	Pass/Fail			Model (Under 70R Loading)	Area	Thickness figure		Thickness configuration	Pass/Fail			
				1 elastomeric layer								1 elastomeric layer				
			Α	2 outer layers	Fail						Α	2 outer layers	Fail			
				2 steel laminates		-					-	2 steel laminates				
				2 elastomeric layer	_							2 elastomeric layer				
			в	2 outer layers	Fail						В	2 outer layers	Fail			
				3 steel laminates								3 steel laminates				
				3 elastomeric layer								3 elastomeric layer				
Model 1	160 x 250		с	2 outer layers	Fail			Model 2	160 x 320		с	2 outer layers	Fail			
				4 steel laminates								4 steel laminates				
				4 elastomeric layer								4 elastomeric layer				
			D	2 outer layers	Fail						D	2 outer layers	Fail			
				5 steel laminates								5 steel laminates				
Model N	otes							Aodel N	lotes							
Area of	160 x '	250 is restricted	l fc	or 70R loadir	o used	in	Area of 160 x 320 is restricted for 70R loading used in									
analysis	100 A 2				ig used		analysis									
anarysis							a	indrysis								
		Desults for Ma	1 1	2						Desults for Ma	4.1	I A				
On anala	-in a Ma	ALED2A ED21		D2C and ED	20 .11	6	0		n e Ma	Results for MC		14 FD4C and ED4				
different	ahaalta 4	ici EDJA, EDJI	o, E baar	ring by IDC	02 har		UII diff	anaryzi	ng WO	ici CD4A, CB4f), f	ring by IDC (D all 0			
amerent	checks I	or elastomeric l	beat	and han as fail	os nav	e	ant		necks I	or elastomeric t	Jea	and han as foll	s nave			
performe	a and are	not wrunn the fi	1111(and hence fail			peri	lormed	anu are	not within the In	mt	and hence faile	zu.			
(Under 70R Loading)	Area	Thickness figure	Thic	kness configuration	Pass/Fail			Model (Under 70R	Area	figure	Thicl	aness configuration Pa	ss/Fail			
			А	2 outer layer	Fail			Loading)				1 elastomeric layer				
				2 steel laminates							A L	2 outer layers	Fail			
				2 elastomeric layer	meric layer		+	2 steel laminates	—							
			в	2 outer layers	Fail						⊾⊢	2 clastometric layer	Fail			
				3 steel laminates							" -	2 outer layers	i au			
				3 elastomeric layer							+	o steel laminates	—			
Model 3	200 x 320		с	2 outer lavers	Fail			Model 4	200 x 400		┝	> elastomeric layer				

1.1 1.1

Fail

Model Notes

analysis

D

Area of 200 x 320 is restricted for 70R loading used in

Model Notes

analysis

4 steel laminates

4 elastomeric laver

2 outer layers

5 steel laminates



Results for Model 5							Results for Model 6								
On analyzing Model EB5A, EB5B, EB5C and EB5D all 6						On analyzing Model EB6A, EB6B, EB6C and EB6D all 6								6	
different	checks	for elastomeri	c bea	aring by IRC	2 83 h	ave	different checks for elastomeric bearing by IRC 83 have								ve
performed and are not within the limit and hence failed.					pe	rformed a	and ar	e no	ot within the	imi	t and hence fa	iled.			
Model (Under 70R Loading)	Area	Thickness figure	Thic	kness configuration	Pass/Fail			Model (Under 70R Loading)	Are	ea	Thickness figure		Thickness configuration	Pass/Fail	
			A	1 elastomeric layer 2 outer layers 2 steel laminates	Fail								A 2 outer layer 2 steel laminates	Fail	
			в	2 elastomeric layer 2 outer layers 3 steel laminates	Fail			Model 6 2					2 elastomeric layer B 2 outer layers 3 steel laminates	Fail	
Model 5	250 x 400		с	3 elastomeric layer 2 outer layers 4 steel laminates	Fail				250 x 5	500			3 elastomeric layer C 2 outer layers 4 steel laminates	Fail	
				4 elastomeric layer						-			4 elastomeric layer		
			D	2 outer layers	Fail								D 2 outer layers	Fail	
				5 steel laminates									5 steel laminates		
Model No	otes						M	odel Note	es				·		
Area of 2	250 x 4	400 is restricte	d for	70R loadin	g used	in	Aı	rea of 250) x 50	0 is	restricted for	70	R loading use	d in	
analysis							an	alysis							
0 1		Results for	Mod	el 7	c 1:00			- I]	Results for M	lode		1. 66	
On analyz	zing Me	odel EB/A, EB	5/B 8	and EB/E all \sim 82 hours nor	6 diff	erent		On analy: backs for	zing	Moc	lel EB8A ai	1d 11	EB8E, all 6	different	
are not wi	thin the	limit and hence	y IKU e fail	ed	Tormed	i and	and are not within the limit and hence failed							•	
On analyz	zing Me	odel EB7C and	EB7	D. all 6 diffe	rent ch	iecks		On analyzing Model EB8B EB8C and EB8D all						Dall 6	j
for elasto	meric l	bearing by IRC	83	have perform	ned and	1 are	ċ	lifferent of	check	s foi	elastomeric	bea	aring by IRC	83 have	;
within the	e limit a	nd hence passed	d.	-			performed and are within the limit and hence passed.								
Model (Under	Area	Thickness figure	Т	hickness configuration	Pass/I	7ail		Model Area Thickness Thickness configuration (Under 70R figure						Pass/Fail	
Loading)				1 elastomeric layer 2 outer layers	Fai	1		Loading)				A	1 elastomeric layer 2 outer layers 2 steel laminates	Fail	
	_		Тв	2 steel laminates 2 elastomeric layer 2 outer layers	Fai	1						в	2 elastomeric layer 2 outer layers 3 steel laminates	Pass	
	-			3 steel laminates		_							3 elastomeric layer		
			c	2 outer layers	Pas	5						с	2 outer layers	Pass	
Model 7	320 x		<u> </u>	4 steel laminates				Model 8	320 x 630				4 elastomeric laver		
	500			4 elastomeric layer	·								2 outer lawara	Page	
			D	2 outer layers 5 steel laminates	Pas	5							5 steel laminates		
	F			4 elastomeric layer	,								5 elastomeric layer		
			E	2 outer layers	Fai	1						E	2 outer layers	Fail	
				5 steel laminates									6 steel laminates		



Model Net						M	Indal Not							
Area of 22	<u>es</u> 0 = 500 ;;	used in englysis				Model Notes								
Area of 52	0 X 500 19	s used in analysis		1 4		Area of 320 x 630 is used in analysis								
Minimum no. of steel laminates can be used = 4						Minimum no. of steel laminates can be used $= 3$								
Maximum	no. of ste	el laminates can	be i	used = 5		Μ	laxımum	no. of ste	ee	el laminates cai	1 be	e used = 5		
Minimum	no. of ela	stomeric layer ca	n b	e used $= 3$		Μ	linimum	no. of ela	lS	tomeric layer o	can	be used $= 2$		
Maximum	no. of ela	stomeric layer ca	n b	e used $= 4$		Μ	laximum	no. of ela	as	stomeric layer	can	be used $= 4$		
Use of ove	rall thick	ness 52 mm to 65	5 m	m is permissib	le with	U	se of ove	erall thick	cn	ness 39 mm to	78	mm is permis	ssible	
5mm side covering.						with 5mm side covering.								
		Results for Mo	del	9					1	Results for Mo	del	1 10		
On analyzi	ng Mode	EB9A and EB9	Е, а	all 6 different cl	hecks for		On analy	zing Mo	de	el EB10A, EB	10E	B, EB10C, EB1	10D and	
elastomeric	e bearing	by IRC 83 hav	ve	performed and	are not		EB10E a	all 6 diff	eı	rent checks fo	r e	lastomeric bea	ring by	
within the	limit and	hence failed.					IRC 83 I	have perf	01	rmed and are v	vith	in the limit an	d hence	
On analyzi	ing Mode	el EB9B, EB9C	an	d EB9D all 6	different	-	passed.							
checks for	elastome	ric bearing by II	RC .	83 have perfor	med and		On anal	yzing M	0	del EB10F, a	16	different che	ecks for	
are within	the limit a	and hence passed	•				elastome	eric bearin	18	g by IRC 83 ha	ve	performed and	l are not	
							within th	ie limit ai	10	hence failed.				
Model (Under 70R	Area	Thickness figure		Thickness configuration	Pass/Fail		(Under 70P	Area		figure	Th	lickness configuration	Pass/Fail	
Loading)			-	1 elastomeric laver			Loading)					1 - 1		
			Α	2 outer layers	Fail						А	2 outer layers	Pass	
				2 steel laminates							2 steel laminates			
				2 elastomeric layer								2 elastomeric layer		
			В	2 outer layers	Pass						в	2 outer layers	Pass	
				3 steel laminates					\vdash		-	3 steel laminates		
				3 elastomeric layer									3 elastomeric layer	
			c	2 outer layers	Pass							с	2 outer layers	Pass
												4 steel laminates		
Model 9	400 x 630			4 steel laminates			Model 10	400 x 800				4 elastomeric layer		
Modely	400 x 050			4 elastomeric layer							D	2 outer layers	Pass	
			Ь	2 outer lavers	Page									
				2 outer highers	1 435							5 steel laminates		
				5 steel laminates								5 elastomeric layer		
				5 alastamaria lavar							_			
				5 elastomeric layer							E	2 outer layers	Pass	
			E	2 outer layers	Fail							6 steel laminates		
				6 steel laminates								6 elastomeric layer		
Model Net			1								F	2 outer layers	Fail	
Area of 400	<u>es</u> 0 - 620 :											7 steel laminates		
Minimum	0×03018	a used in analysis		a = 2			Model N	lotes			1	1		
Minimum no. of steel laminates can be used $= 3$						Area of	400 x 800) i	is used in analy	vsic	1			
Maximum no. of steel laminates can be used = 5						Minimu	mno of c	, 1	eel laminates o	, 513 911	he used – ?			
Minimum no. of elastomeric layer can be used $= 2$						Maximu	m no. of s	01 0+	cel laminator	an	be used -6			
Maximum no. of elastomeric layer can be used $= 4$					Naximum no. of steel laminates can be used $= 6$									
Use of ove	erall thick	tness 26 mm to 0	55	mm is permiss	ible with		Mortin		.10	lostomente laye		u = u = u = u = 1		
5mm side o	covering.						Iviaximu	111 110. OI (e1	astomeric laye	1 C	an de used = 5 78 mm :	mica:1-1	
							Use of c	overall th	10	ckness 26 mm	to	/8 mm is per	missible	
							with 5m	m side co	V	ering.				

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VII. CONCLUSIONS

This project concluded that the simulation for 70R loading on different elastomeric pad dimensions, comparing each model having each variants, some model variants are failed but some are passed. Details of recommended variants are mentioned below:-Table 5: Passed models recommendation

Model (Under 70R Loading)	Area	Thickness figure	Th	ickness configuration	Passed models	
				3 elastomeric layer		
Model 7	320 x 500		С	2 outer layers	Pass	
				4 steel laminates		
				4 elastomeric layer		
Model 7	320 x 500		D	2 outer layers	Pass	
				5 steel laminates		
				2 elastomeric layer		
Model 8	320 x 630		В	2 outer layers	Pass	
				3 steel laminates		
				3 elastomeric layer		
Model 8	320 x 630		C	2 outer layers	Pass	
				4 steel laminates	1	
				4 elastomeric layer		
Model 8	320 x 630		D	2 outer layers	Pass	
				5 steel laminates		



			2 elastomeric layer		
Model 9	400 x 630	В	2 outer layers	Pass	
			3 steel laminates		
			3 elastomeric layer		
Model 9	400 x 630	С	2 outer layers	Pass	
			4 steel laminates		
			4 elastomeric layer		
Model 9	400 x 630	D	2 outer layers	Pass	
			5 steel laminates		
Model 10			1 elastomeric layer		
	400 x 800	А	2 outer layers	Pass	
			2 steel laminates		
			2 elastomeric layer	Pass	
Model 10	400 x 800	В	2 outer layers		
			3 steel laminates		
			3 elastomeric layer		
Model 10	400 x 800	С	2 outer layers	Pass	
			4 steel laminates	1	
			4 elastomeric layer		
Model 10	400 x 800	D	2 outer layers	Pass	
			5 steel laminates		

And in Applied Science Contractions

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