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Maximizing the pre-engineered construction market

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ABSTRACT:

The use of pre-engineered structures has increased significantly in recent years. The main benefits are speedy construction and high quality control. On the other hand, its economy is mostly unknown. The building's cost is affected by the gable's slope, spans, and bay spacing. Keeping these characteristics in mind while building gable frames for typical loads like those listed above is essential, since they are updated throughout time in this article. Once the amount is known, the most cost-effective option is shown in each case.
To avoid confusion, "pre-engineered building" refers to prefabricated structures that are assembled in a factory.

INTRODUCTION

It is possible to create a steel structure of exceptional quality and accuracy by manufacturing framing members and other components in a factory and then shipping them to the construction site for use as bolts and nuts in the final assembly process. The nut-bolt system eliminates the requirement for on-site welding in traditional steel fabrication. These constructions use hot rolled tapered sections and cold rolled sections (usually "Z" and "C" sections) as per the internal stress requirements, resulting in less steel waste and lighter foundations owing to the reduced weight and self-weight of the structure.. Standard standards for metal building manufacturers Association (MBMA) allow the use of built-up sections with a 3.5 mm thickness, rather than six millimetres required for typical steel sections. The use of high-strength steel (345MPa) and tapered profiles demonstrate that steel may be more effectively used for increased strength. Tapered section theory was established in America by use of the bending moment diagram. At larger bending moment values, resistance increases, while depths decrease. PEB's Moment of inertia (I) varies with depth, which makes it different from ordinary steel sections. When it comes to PEBs, expanding their depth has an exponential power of three, therefore it's a no-brainer to either lessen or boost their strength.

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LITARATURE REVIEW

The usage of pre-engineered buildings in industrial construction has just lately started. Smallness and cheap cost contribute to the versatility of this method, which makes it suitable for a wide range of tasks. To supply as much as possible is one of the guiding principles. This design offers many advantages over a conventional steel construction (CSB). Research has shown that CSB constructions are more costly and time-consuming to build than PEB structures, according to findings. Since India is one of the world's fastest-growing economies, infrastructure development is essential. Prefabricated structures have a lot of space to grow in India because of the country's fast population growth. As a result, PEB in India is still a relatively new field. Only a tiny number of academic studies have looked at the use of IS 800 instead of AISC for creating PEBs. A higher level of safety is provided by tougher building requirements in India compared to other countries.

OBJECTIVE

Steel is minimised to the greatest extent possible in PEB buildings. The roof angle, bay spacing, and span length are only few of the aspects to keep in mind (S). Is 875, which provides typical load combinations, is used to evaluate this structure. The least quantity of steel is produced when certain conditions are observed and reported.

SALIENT FEATURES AND IMPORTANT DIMENSIONS

The 7.0m height pre-engineered rigid frame of tapered sections with bolted connections shown in fig

Structural Details

1. Height – 7m
2. Ridge angles – $2^0.86,6^0.5,10^0$
3. Bay spacing - 5.5,6.5,7.5,8.5
4. span varying – 25,30,40m
5. Grade of steel – 340mpa
6. Type of Soil = soft soil
7. Basic wind speed = 55 m/sec
8. Earthquake zone = III

Analysis begins with a sample size of 1. The findings of the analysis are acquired by changing one parameter at a time while keeping the other two parameters constant.

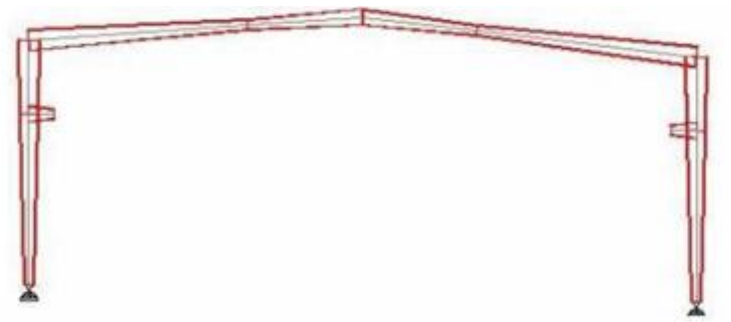

Fig1-: pre-engineered rigid frame.

Modeling

The analysis is carried out with the aid of STAAD PRO V8i. It is necessary to examine the combined effects of dead, live, wind, and seismic loads as specified by IS 875. Procedures for dealing with wind and seismic loads are static in nature. Changes have been made one at a time, while holding constant the other parameters, such as: roof inclination (), bay spacing (B), and span length (S). Production of steel has been slashed due to a variety of factors.

Material

340Mpa yield strength and 2.0 x1011 N/m2 Young's modulus (E) for the material used in the PEB construction.

RESULTS AND DISCUSSION

Table 1				S = 25m
MAX VALUE OF BASE REACTION AT EXTREME COLUMN (kN)				
θ\B	5.5m	6.5m	7.5m	8.5m
$2^0.86$	145.065	170.507	189.51	220.082
$6^0.5$	146.193	172.273	196.89	221.763
10^0	148.268	175.148	198.644	223.691

Table 1 shows that with a roof angle of 100 and a bay spacing of 8.5m, the greatest value of base reaction occurs at an extreme column. Roof angle does not seem to have a significant effect on the base response, although bay spacing does. A distance between the bays of 8.5 metres results in the greatest base reaction of 223.691 kN.

Table 2				S = 25m
MAXIMUM VALUE OF MOMENT AT BEAM COLUMN JUNCTION(kNm)				
θ\B	5.5m	6.5m	7.5m	8.5m
$2^0.86$	527.12	679.42	679.42	852.4
$6^0.5$	542.16	643.55	717.49	772.33
10^0	544.82	625.5	712.55	811.94

Various inclinations of the roof angle () and bay spacing are listed in table 2 for the greatest value moments (B). The maximum moments at the beam column junction may also be found to rise with bay separation. When = 20.86 and the bay spacing is 8.5m, the greatest moment is 811.94kNm.

Table 3				S = 25m
MAXIMUM VALUE OF MOMENT AT RIDGE OF RAFTER(kNm)				
θ\B	5.5m	6.5m	7.5m	8.5m
$2^0.86$	37.74	52.16	36.98	35.645
$6^0.5$	32.51	29.42	62.52	76.3
10^0	46.88	64.74	78.03	82.05

With regard to angle () and bay spacing, the maximum moment values are shown in table – 3. (B). Furthermore, it can be noted that as bay spacing grows, the maximum moment at the rafter's ridge rises as well. For = 100, when the ridge angle is increased for all bay spacings, the maximum moment increases as well. When = 100 and bay spacing is 8.5m, the maximum moment is 82.05.

Table 4				S = 25m
MAXIMUM VALUE OF HORIZONTALDISPLACEMENT AT BEAM COLUMN JUNCTION(mm)				
θ\B	5.5m	6.5m	7.5m	8.5m
$2^0.86$	19.19	16.227	17.466	16.415
$6^0.5$	14.545	8.731	11.063	12.443
10^0	14.105	8.026	9.595	10.568

For varying inclinations of angle () and bay spacing, four maximum values of displacement at the beam-column junction are shown in table 1. (B). As the angle of the roof rises, the displacement reduces, but the bay spacing does not change in a specific pattern. When = 20.86 and the bay separation is 5.5m, the maximum displacement is 19.19mm.

Table 5				S = 25m
MAXIMUM VALUE OF HORIZONTAL DISPLACEMENT AT RIDGE OF RAFTER(mm)				
θ\B	5.5m	6.5m	7.5m	8.5m
$2^0.86$	19.19	16.227	17.466	16.415
$6^0.5$	11.378	8.731	11.063	12.443
10^0	14.105	8.026	9.072	10.568

Displacement at the ridge of a rafter may be measured at five different angles and bay spacings in a table - 5. (B). Displacement does not follow a certain pattern as the roof angle and bay spacing increase. For example, with a radius of 20.86 and bay spacing of 5 metres, the maximum displacement occurs at 19.19mm, or 19.19mm.

Table 6				S = 25m
MAXIMUM VALUE OF VERTICAL DEFLECTION AT RIDGE OF RAFTER(mm)				
θ\B	5.5m	6.5m	7.5m	8.5m
$2^0.86$	43.392	39.126	41.287	39.256
$6^0.5$	41.96	31.816	37.978	42.124
10^0	43.279	28.306	32.22	36.701

There are six maximum values of vertical deflection at the rafter ridge for different inclinations of angle () and bay spacings shown in the table below (B). As the angle of the roof and the distance between the bays increases, this may be seen. Is there a certain pattern to how the displacement occurs? When = 20.86 and bay spacing is 5.5m, the maximum deflection is 43.392mm.

Table 7				S = 25m
STEEL CONSUMPTION(kg/m²)				
θ\B	5.5m	6.5m	7.5m	8.5m
$2^0.86$	23.20	22.05	20.62	19.32
$6^0.5$	23.74	23.12	21.11	19.81
10^0	24.87	24.77	21.09	19.74

A 25-meter frame span consumes more steel as the angle () increases, but as bay spacing increases, steel consumption decreases. This can be seen in table 7. Steel consumption is 19.32kg/m2 when = 20.86 and bay spacing is 8.5m, according to table 7's minimum consumption.

Table 7a				S = 25m
MOMENT INTERACTION RATIO				
θ\B	5.5m	6.5m	7.5m	8.5m
$2^0.86$	0.911-0.954	0.904-0.916	0.885-0.951	0.934-0.979
$6^0.5$	0.948-0.978	0.917-0.997	0.904-0.949	0.922-0.965
10^0	0.897-0.967	0.859-0.945	0.929-0.964	0.912-0.991

In order to ensure that the design is secure, the interaction ratio should never be more than unity (see tables 7a, 8a, and 9a). While maintaining a value of about 0.9 and higher, it is always less than unity for economic reasons.

Table 8				S = 30m
STEEL CONSUMPTION(kg/m²)				
θ\B	5.5m	6.5m	7.5m	8.5m
$2^0.86$	38.61	35.25	33.26	28.03
$6^0.5$	29.29	25.90	22.25	24.19
10^0	27.49	26.26	24.94	22.94

For a 30m frame span, the angle () shows a significant drop in steel consumption, whereas along the bay spacing, steel consumption reduces as the bay spacing rises (see table 8). When = 60.5 and bay spacing is 7.5m, the minimal steel consumption from table 8 is 22.25kg/m2.

Table 8a				S = 30m
MOMENT INTERACTION RATIO				
θ\B	5.5m	6.5m	7.5m	8.5m
$2^0.86$	0.913-0.981	0.908-0.952	0.910-0.987	0.931-0.964
$6^0.5$	0.952-0.993	0.886-0.982	0.896-0.969	0.932-0.985
10^0	0.905-0.970	0.887-0.959	0.946-0.973	0.946-0.958

Table 9				S = 40m
STEEL CONSUMPTION(kg/m^2)				
θ\B	5.5m	6.5m	7.5m	8.5m
$2^0.86$	37.42	34.22	36.83	25.42
$6^0.5$	33.58	27.50	26.16	25.51
10^0	32.97	27.83	26.34	24.84

Table 9 shows that for a frame span of 40m, consumption of steel does not follow a defined pattern as the angle () and bay spacing increase. Table 9 shows that when = 100 and the bay spacing is 8.5m, the minimal steel usage is 24.84kg/m2.

Table 9a				S = 40m
MOMENT INTERACTION RATIO				
θ\B	5.5m	6.5m	7.5m	8.5m
$2^0.86$	0.947-0.987	0.914-0.994	0.964-0.986	0.927-0.984
$6^0.5$	0.887-0.964	0.899-0.985	0.886-0.989	0.886-0.946
10^0	0.843-0.973	0.939-0.984	0.888-0.997	0.900-0.991

Table - 10			θ = $2^0.86$
MAX VALUE OF BASE REACTION AT EXTREME COLUMN(kN)			
B\S	25m	30m	40m
5.5m	153.66	186.78	260.74
6.5m	178.09	215.68	298.70
7.5m	202.51	244.58	336.67
8.5m	227.04	273.48	374.63

An extreme column with an angle of 100 and a space between bays of 8.5 metres and a span of 40 metres has the highest value of the base response, as shown in table 10. As the width and bay spacing grow, the base response tends to rise.

Table - 11			θ = $2^0.86$
MAXIMUM VALUE OF MOMENT AT BEAM COLUMN JUNCTION(kNm)			
B\S	25m	30m	40m
5.5m	527.12	880.71	1650.73
6.5m	679.42	943.24	1721.6
7.5m	729.79	1061.98	2190.58
8.5m	852.4	1325.23	2300.54

Those maximum moments are shown in the table- 11 for varied bay spacing and spans (B) (S). Moments grow as bay spacing and span increase, as may be seen. There seems to be a distinct pattern to the growth. When the bay spacing is 8.5m and the span is 40m, the greatest moment is 2300.54kNm.

Table - 12			θ = $2^0.86$
MAXIMUM VALUE OF MOMENT AT RIDGE OF RAFTER(kNm)			
B\S	25m	30m	40m
5.5m	37.74	109.16	128.33
6.5m	52.16	21.26	212.55
7.5m	36.98	48.75	266.65
8.5m	35.645	167.8	384.49

With regard to bay spacing (B) and spans (S), the maximum value of moments is shown in table – 12. (S). As the span rises, so do the moments, but there doesn't seem to be a pattern along the bay spacing where the moments increase. When the bay spacing is 8.5m and the span is 40m, the greatest moment is 384.49kNm.

Table - 13			θ = $2^0.86$
MAXIMUM VALUE OF HORIZONTAL DISPLACEMENT AT BEAM COLUMN JUNCTION (mm)			
B\S	25m	30m	40m
5.5m	19.19	7.454	11.221
6.5m	16.222	8.951	10.189
7.5m	17.466	8.325	9.418
8.5m	16.415	7.386	7.798

For different bay spacings (B) and spans, the maximum horizontal displacement at beam column junction is shown in the table (S). Similarly, when the distance between the bays becomes wider, the displacement gets smaller, whereas as the span is longer, the displacement gets smaller, then bigger. When the bay spacing is 5.5m and the span is 25m, the maximum displacement is 19.19mm.

Table - 14			$\theta = 2^0.86$
MAXIMUM VALUE OF HORIZONTAL DISPLACEMENT AT RIDGE OF RAFTER(mm)			
θ\B	25m	30m	40m
5.5m	18.985	7.854	9.841
6.5m	18.227	8.951	7.445
7.5m	17.466	8.325	6.749
8.5m	16.415	7.386	5.954

Maximum horizontal displacement at the ridge of the rafter for varied bay spacing (B) and span lengths (S) is listed in the table (S). As bay spacing grows, the displacement reduces, however as span rises, there is no clear pattern to the increase in displacement. When the bays are spaced out 5.5 metres apart and the span is 25 metres, the maximum displacement is 18.985 millimetres.

Table - 15			$\theta = 2^0.86$
MAXIMUM VALUE OF VERTICAL DEFLECTION AT RIDGE OF RAFTER(mm)			
θ\B	25m	30m	40m
5.5m	43.392	47.395	122.916
6.5m	39.126	50.239	124.36
7.5m	41.287	44.753	99.961
8.5m	39.256	46.083	127.509

For different bay spacings (B) and spans (S), the maximum value of vertical deflection at the ridge of the rafter is shown in the table - 15. (S). As the span length rises, the deflection increases, however the deflection along bay spacing does not follow a certain pattern. When the bay spacing is 8.5m and the span is 40m, the maximum deflection is 127.509mm.

Table - 16			$\theta = 2^0.86$
STEEL CONSUMPTION(kg/m^2)			
B\S	25m	30m	40m
5.5m	23.20	38.61	37.42
6.5m	22.05	35.25	34.22
7.5m	20.62	33.26	36.83
8.5m	19.32	28.03	25.42

Although steel consumption falls for 25 to 30 m, 30 to 40 m, and 40 to 50 metres as the distance between bays grows (Table 16), it does not seem to have any distinct pattern when it comes to spans greater than 50 metres. For 8.5m bay spacing and a 25m span, a minimum density of 19.32kg/m2 is achieved.

Table – 16a			$\theta = 2^0.86$
MOMENT INTERACTION RATIO			
B\S	25m	30m	40m
5.5m	0.911-0.954	0.913-0.981	0.947-0.987
6.5m	0.904-0.916	0.908-0.952	0.914-0.994
7.5m	0.885-0.951	0.910-0.987	0.964-0.986
8.5m	0.934-0.979	0.931-0.964	0.927-0.984

Table 16a, 17a, and 18a gives the moment interaction factor which are kept close to unity but always less then unity.

Table - 17			$\theta = 6^0.5$
STEEL CONSUMPTION(kg/m^2)			
B\S	25m	30m	40m
5.5m	23.74	29.29	33.58
6.5m	23.12	25.90	27.50
7.5m	21.11	22.25	26.16
8.5m	19.81	24.19	25.51

Table 17 shows that the consumption of steel decreases as the bay spacing increases, while the consumption of steel increases as the span increases. For 8.5m bay spacing and a 25m span, a minimum of 19.81kg/m2 is achieved.

Table - 17a			$\theta = 6^0.5$
MOMENT INTERACTION RATIO			
B\S	25m	30m	40m
5.5m	0.948-0.978	0.952-0.993	0.887-0.964
6.5m	0.917-0.997	0.886-0.982	0.899-0.985
7.5m	0.904-0.949	0.896-0.969	0.886-0.989
8.5m	0.922-0.965	0.932-0.985	0.886-0.946

Table 18 shows that the use of steel lowers as the bay spacing rises, but the consumption of steel increases when the span grows. For 8.5m bay spacing and a 25m span, a minimum density of 19.74kg/m2 is achieved.

Table - 18			$\theta = 10^0$
STEEL CONSUMPTION(kg/m^2)			
B\S	25m	30m	40m
5.5m	24.87	27.49	37.97
6.5m	24.77	26.26	27.83
7.5m	21.09	24.94	26.34
8.5m	19.74	22.94	24.84

Table – 18a			$\theta = 10^{0}$
MOMENT INTERACTION RATIO			
B\S	25m	30m	40m
5.5m	0.897-0.967	0.905-0.970	0.843-0.973
6.5m	0.859-0.945	0.887-0.959	0.939-0.984
7.5m	0.929-0.964	0.946-0.973	0.888-0.997
8.5m	0.912-0.991	0.946-0.958	0.900-0.991

Table - 19				$\theta = 2^{0}.86$
MAX VALUE OF BASE REACTION AT EXTREME COLUMN(kN)				
S\B	5.5m	6.5m	7.5m	8.5m
25m	145.065	170.51	189.51	220.082
30m	186.456	339.15	248.25	274.68
40m	381.307	425.13	518.93	568.813

Table - 20				$\theta = 2^{0}.86$
MAXIMUM VALUE OF MOMENT AT BEAM COLUMN JUNCTION(kNm)				
S\B	5.5m	6.5m	7.5m	8.5m
25m	527.12	679.42	729.79	852.4
30m	880.71	943.24	1061.9	1325.23
40m	1650.73	1721.6	2190.58	1299.83

Table – 21				$\theta = 2^{0}.86$
MAXIMUM VALUE OF MOMENT AT RIDGE OF RAFTER(kNm)				
S\B	5.5m	6.5m	7.5m	8.5m
25m	37.74	52.16	36.98	35.645
30m	109.16	30.0	48.75	167.8
40m	128.33	212.55	266.65	384.49

Table – 22				$\theta = 2^{0}.86$
MAXIMUM VALUE OF HORIZONTAL DISPLACEMENT AT BEAM COLUMN JUNCTION(mm)				
S\B	5.5m	6.5m	7.5m	8.5m
25m	19.19	16.227	17.466	16.415
30m	7.454	8.951	8.325	7.386
40m	11.221	10.189	7.798	9.935

Table – 23				$\theta = 2^{0}.86$
MAXIMUM VALUE OF HORIZONTAL DISPLACEMENT AT RIDGE OF RAFTER(mm)				
S\B	5.5m	6.5m	7.5m	8.5m
25m	19.19	16.227	17.466	16.415
30m	7.854	8.951	8.325	7.386
40m	9.841	7.445	5.233	6.749

Table – 24				$\theta = 2^{0}.86$
MAXIMUM VALUE OF VERTICAL DEFLECTION AT RIDGE OF RAFTER(mm)				
S\B	5.5m	6.5m	7.5m	8.5
25m	51.914	39.126	41.287	39.256
30m	99.893	50.239	44.753	46.083
40m	281.45	124.36	99.961	127.509

Table - 25				$\theta = 2^{0}.86$
STEEL CONSUMPTION(kg/m^2)				
S\B	5.5m	6.5m	7.5m	8.5m
25m	23.20	22.05	20.62	19.32
30m	38.61	35.25	33.26	28.03
40m	37.42	34.22	36.83	25.42

Tables 19 to 25 show the same results, as well. Finally, it explains itself. As the span expands, steel consumption rises, but as the bay spacing increases, steel consumption decreases. A density of 19.32kg/m2 is attained with an 8.5m bay spacing and a 25m span.

Table - 25a				$\theta = 2^{0}.86$
MOMENT INTERACTION RATIO				
S\B	5.5m	6.5m	7.5m	8.5m
25m	0.911-0.954	0.904-0.916	0.885-0.951	0.934-0.979
30m	0.913-0.981	0.908-0.952	0.910-0.987	0.931-0.964
40m	0.947-0.987	0.914-0.944	0.964-0.986	0.927-0.984

Design safety dictates that the interaction ratio should never exceed one in any of the tables listed above (Tables 25a, 26a, and 27a). While maintaining a value of about 0.9 and higher, it is always less than unity for economic reasons.

Table - 26				$\theta = 6^{0}.5$
STEEL CONSUMPTION(kg/m^2)				
S\B	5.5m	6.5m	7.5m	8.5m
25m	23.74	23.12	21.11	19.81
30m	29.29	25.90	22.25	24.19
40m	33.58	27.50	26.16	25.51

Table - 26a				$\theta = 6^{0}.5$
MOMENT INTERACTION RATIO				
S\B	5.5m	6.5m	7.5m	8.5m
25m	0.948-0.978	0.917-0.997	0.904-0.949	0.922-0.965
30m	0.952-0.993	0.886-0.982	0.896-0.969	0.932-0.985
40m	0.887-0.964	0.899-0.985	0.886-0.989	0.886-0.946

Table - 27				$\theta = 10^0$
STEEL CONSUMPTION(kg/m2)				
S\B	5.5m	6.5m	7.5m	8.5m
25m	24.87	24.77	21.09	19.74
30m	27.49	26.26	24.94	22.94
40m	32.97	27.83	26.34	24.84

Table - 27a				$\theta = 10^0$
MOMENT INTERACTION RATIO				
S\B	5.5m	6.5m	7.5m	8.5m
25m	0.897-0.967	0.859-0.945	0.929-0.964	0.912-0.991
30m	0.905-0.970	0.887-0.959	0.946-0.973	0.946-0.958
40m	0.843-0.973	0.939-0.984	0.888-0.997	0.900-0.991

For example, as can be shown in tables 26 and 27, increasing the span increases steel usage, but increasing the distance between the bays lowers steel use. Similar findings may be seen in both sets of data. Table 26 shows a minimum value of 19.81kg/m2 for a span of 25 metres and a bay spacing of 8.5 metres, respectively. Table 27 shows a minimum value of 19.74kg/m2 for a span of 25 metres and an interval of 8.5 metres between bays.

CONCLUSION

This project aims to reduce the amount of steel used in a PEB one-story industrial shed with a gable roof. Responses, moments, and displacements are all influenced by angle, bay spacing (B), and span (S) (S).

Table 7 illustrates a range of 25-meter spans, bay spacings, and roof angles. This combination results in the lowest possible steel use, as seen in the table below.

MINIMUM STEEL CONSUMPTION

Table - 28	Absolute minimum steel consumption			
	Bay spacing(B)	Span(S)	Ridge angle (θ)	Steel consumption(kg/m^2)
1.	8.5m	25m	$2^0.86$	19.32
2.	8.5m	25m	$6^0.5$	19.81
3.	8.5m	25m	10^0	19.74

Table 28 presents a variety of minima for different Q, B, and S combinations, as shown in the picture. S = 25m, B = 8.5m, and S=19.32 kg/m2 is the bare essential steel combination.

Table 8 shows a decrease in steel consumption as a consequence of these changes. A look at the table below reveals the lowest possible steel usage.

For S = 30 m, = 60.5 m, and B = 7.5 m, it requires 22.25 kilogrammes of steel per square metre.

Table 9 shows how steel consumption fluctuates with variations in span, bay spacing, and roof angle. This combination results in the lowest possible steel use, as seen in the table below.

Steel consumption is 24.84kg/m2 for S = 40m, = 100, and B = 8.5.

As a consequence, the optimal steel consumption for the bay spacing is 19.32 kg/m2 for a zone III industrial structure with ridge frames and other assumed data.

() = 20,86° is the angle measurement for () = 8.5 m, () = 25 m, and () = () A wide range of factors, such as earthquake and wind zones and steel grade as well as soil type, crane and multi-span frames, would have a varied effect.

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