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Research article

Effect of haunch on the stresses of box culvert

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Abstract: Culverts are often required under earth embankment to allow for the crossing of a watercourse, like streams, to prevent the road embankment from obstructing the natural waterway. The opening of the culvert is determined based on the waterway required to accommodate the design flood, whereas the thickness of the culvert section is designed based on the loads applied to the culvert. From the previous literature review, it is noted that the effect of haunch on the stresses of the culvert was not studied. Therefore, this research focuses on the impact of using haunches on the economy of the culvert design. This paper studies some design parameters of box culverts, such as the thickness of the haunch, the coefficient of earth pressure, the thickness of box culvert, and depth of fill on the top slab. The objectives show the effect of haunch on the stresses of the box culvert. The study investigated the variation in stresses and the cost comparison made for different width of the box culvert. The percentage reduction in the cost of culvert based on the presence of haunch is presented. At last, several significant conclusions are given based on numerical results as the presence of haunch is the best solution for decreasing the values of stresses from the economic point of view.

Keywords: box culverts; haunch; cushion; earth pressure; surcharge loading; breadth of the culvert

1. Introduction

Culverts can be of different shapes such as arch, slab, and box. They are constructed of brick, stone, or reinforced concrete. Reinforced concrete box culvert consists of top slab, bottom slab and vertical walls built monolithically to form a closed rectangular or square single or multiple cells. Box culverts may be either an inverted U on a concrete base foundation (crown unit) or a U-shaped trough with a lid (inverter unit). By using one or more intermediate vertical wall, multiple cell box culverts are formed. Vent size of the culvert is determined based on flood discharge from the upstream side. Since culvert passes through the earth embankment, it is subjected to the same traffic loads as the road and therefore designed for such loads. The major reason box culverts are favored for this type of construction is that they are a cost-effective means of construction, yielding the desired useful lifespan with minimal maintenance. Box culverts can be installed quickly reducing the road closure time required for replacement of a bridge. The analysis of box culvert is based on a set of loading conditions, which the component must withstand. These loads may vary depending on the direction of action, type of deformation, and nature of the structural action. They may be vertical uniform distributed load, the weight of sidewalls, and lateral earth pressure on vertical sidewalls.

Sinha BN and Sharma RP [1] provided a full discussion on the provisions in the Codes, considerations, and justification of the aspects of design. The study concluded that the box for cross drainage works across high embankments has many advantages compared to a slab culvert. Maximos H [2] et al., summarized the experimental program to evaluate the fatigue effects on reinforced concrete (RC) box culverts and the resulting recommendations that were made to the (AASHTO). Test results show a good distribution of the load resistance between the two reinforcement directions in box culvert sections. Shreedhar S and Shreedhar R [3] evaluated design coefficients for bending moment, shear force and normal thrust for various loading cases for different ratios of L/H = 1.0, 1.25, 1.5, 1.75 and 2.0 for three cell box culvert. This study concluded that the critical sections considered are the span center of the top and bottom slabs and support sections and at the center of the vertical walls. Chandrakant LA and Malgonda PV [4] developed an excel program for analysis and it is compared with software results. This study concluded that the case of loading that yields the maximum moment is when box culvert is empty, with live load surcharge on the top slab of the box and superimposed surcharge load on earth fill. Kalyanshetti MG and Gosavi SA [5] analyzed 12 m channel length with 2 m to 6 m height variation, which is divided into a single cell, double cell, and triple cell. The analysis was done by using the stiffness matrix method and a computer program in C language developed for the cost evaluation. The study carried out related to variation in bending moment; subsequently, a cost comparison was made for different aspect ratios. Kolate N [6] et al. studied some design parameters of box culverts like the angle of dispersion, the effect of earth pressure and depth of cushion provided on the top slab of box culverts. This study concluded that the box without cushion having low design moments and shear stress as compared to the box having the cushion.

Sahu KK and Sharma S [7] compared the cost with and without considering the optimum thicknesses. An attempt is made to generate charts of bending moments for the top and bottom slabs, such that from these charts the values of bending moments can be evaluated at any intermediate aspect ratio. Kumar YV and Srinivas C [8] found out stresses such as bending moment and shear force of the structure under railway loading and these stresses computed by computational methods as well as conventional methods. They concluded that the finite element method gives the less value of stresses than grillage and the conventional method. Patel AD and Galatage AA [9] studied the behavior of the box culvert with cushion and without cushion load for different aspect ratios, also the effect of different load combinations which will produce the worst effect of the safe structural design. This study concluded that, the load combination with empty box found to be the critical combination of all values of aspect ratios under consideration. Krishna SR and Rao ChH [10] identified the behavior of box culvert with and without the interaction of soil. This study concluded that the bending moment values of the top slab increased by 19% without soil interaction condition when compared to soil interaction. Saurav and Pandey I [11] presented a comparative study of the analysis of the conventional method using STAAD software and FEM using ANSYS software. The study concluded that the culvert design through finite element method would not only save material and money but also make the design safer. Polra AR [12] et al., presented a review on the analysis and cost-comparison of box culvert for the different aspect ratio of the cell. They concluded that greater stresses are found in box culvert structures without cushion, compare to box culvert with cushion. Besides, if the angle of dispersion is 0°, the intensity of the live load is maximum.

Qiang Ma [13] et al., investigated in the tests, the distribution and the growth of the earth pressures on the top slab and the lateral walls and the displacements and the deformations of the top slab and lateral walls. The results show that the deflections of the lateral walls and of the cover slab are very small, and the variation of distribution and growth of the earth pressures presents significantly nonlinear characters, which is totally different from the linear earth pressure theory proposed by the current Chinese code. Vasu Shekhar Tanwar [14] et al., tried to reduce the Bending Moment values and displacement values in order to make structure more safe and reliable to construct and use. They concluded the displacement values and bending moment values declined and gave a positive response for structural change. Elie Awwad [15] et al., presented the results of a parametric study of wheel load distribution in four sided precast concrete box culverts using three-dimensional finite element analysis as compared to the two-dimensional plane frame analysis. It was shown that the plane frame analysis and 3D-FEA gave similar results for long-span and non-standard box culverts. Roshan Patel, and Sagar Jamle [16] deal with complete design of box culvert manually and studied the design parameters such as effect of earth pressure, In this work conclusions made on the basis of bending moments and shear forces with and without cushioning cases. They concluded that the small variations in coefficient of earth pressure observed have very small influence on design of box culverts without cushioning. It is easy to judge the variations observed in percent as per different classes of loading.

From the previous literature review, we did not find the effect of haunch on the stresses of the culvert so this paper studied it

2. Methodology

The finite element method (FEM) is a numerical technique; represents the solid element as a group of nodes and meshes. The solution of this method is made by assuming displacement function to describe the displacements within the element instead of the infinite series for the whole solid. This study used finite elements to analyze the behavior of box culvert by the 3d model; the cross-section and 3D of the model is presented in Figure 2. Eight-node solid element was proposed throughout the model. The use of this element increases the accuracy of the results. The boundary conditions of the model are springs at the bottom of the culvert. The steps of methodology is shown in Figure 1.

3. Analysis section

The box culvert under consideration is shown in Figure 2. It is studied by using (SAP2000) program to calculate the stresses and to explain the elastic behavior of a box culvert under variable loads, by changing some parameters such as width (B) and thickness (t) of the culvert, and the dimensions of the haunch, (dh).

The earth pressure on vertical sidewalls of the box culvert is computed according to the Coulomb's Theory. The earth pressure intensity is given by $P = Ki\ \rho\ H$, where Ki is a coefficient of active earth pressure, ρ is the density of soil and H is the vertical height of the box. The earth can exert pressure on the sidewall, minimum as active and maximum as passive, or in between (called at-rest pressure). The value of Ki depends on the site condition. If the structure was constructed before the backfilling of earth, the coefficient of earth pressure should be taken at rest. In such a situation, the value of the coefficient of earth pressure shall be more than the active condition. The coefficient of earth pressure in case of box culvert is taken as 0.333 for soil having φ = 30°. The density of soil is 1.8 t/m^3, the unit weight of concrete is 2.5 t/m^3, the cushion is 50 cm, and the live load is 0.4 t/m^2.

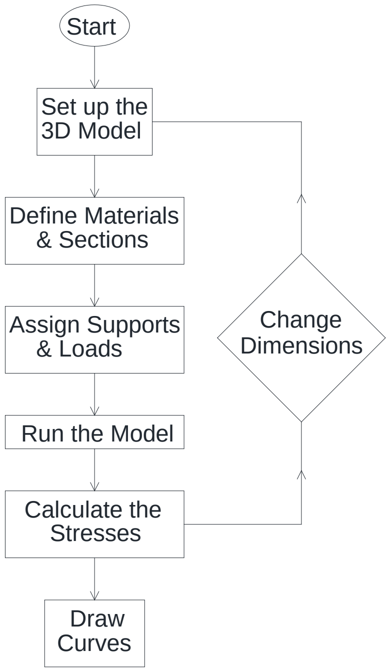


Figure 1. The flowchart of research methodology.

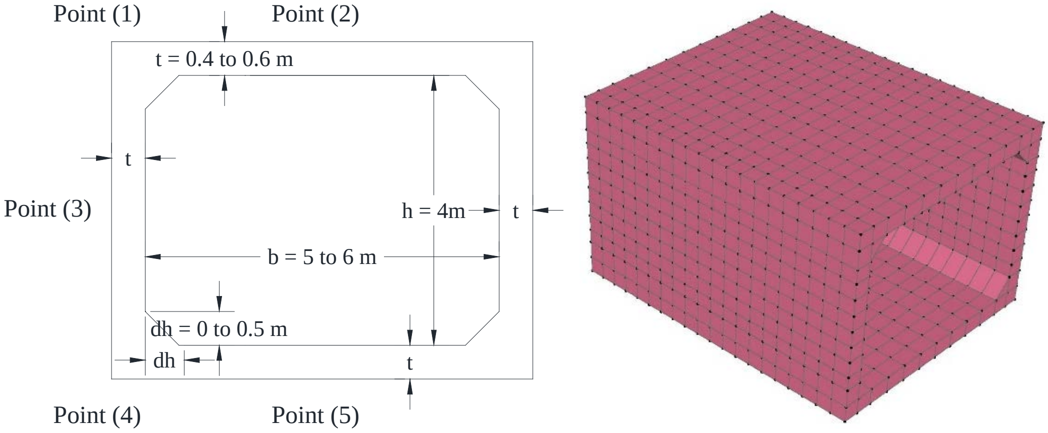


Figure 2. Points of calculating stresses and 3D model.

The geometry of the culvert is part of the parametric study. The width of the culvert was varied from 5.0 m to 6.0 m, the height of the culvert was taken 4.0 m, the thickness of the culvert was varied from 0.4 m to 0.6 m, dimensions of the haunch was varied from 0 m to 0.5 m.

Points of calculating stresses are: two points in the middle of the slabs (top and bottom), two points at the rigid zones (corners) and one point in the middle of the wall.

Model parameters for linear elastic are: density 2.5 t/m^3, modulus of elasticity 2534563.6 t/m^2, and Poisson ratio 0.2

4. Results

To assess the impact of introducing haunches for the culvert, the normal stresses are computed, using finite element method. The stresses in the horizontal direction (S11) and in the vertical direction (S22) are computed and compared for each configuration.

- Case b = 6 m

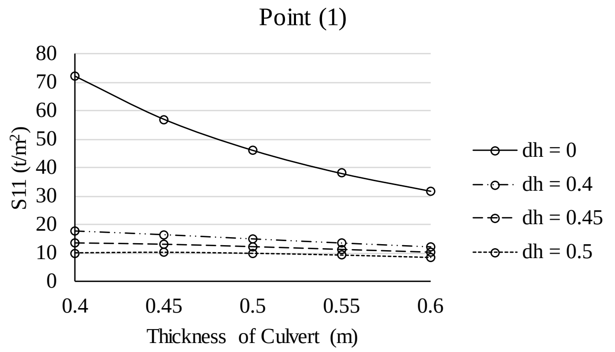


Figure 3a. S11 at point (1) for case b = 6 m.

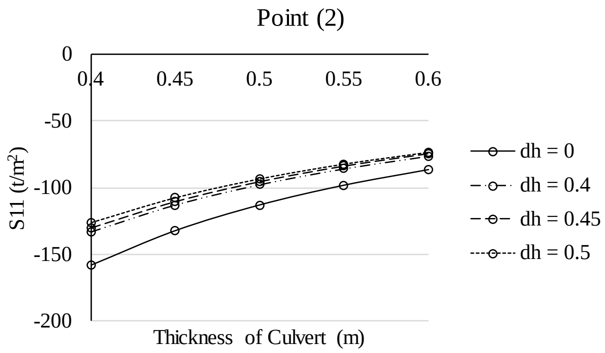


Figure 3b. S11 at point (2) for case b = 6 m.

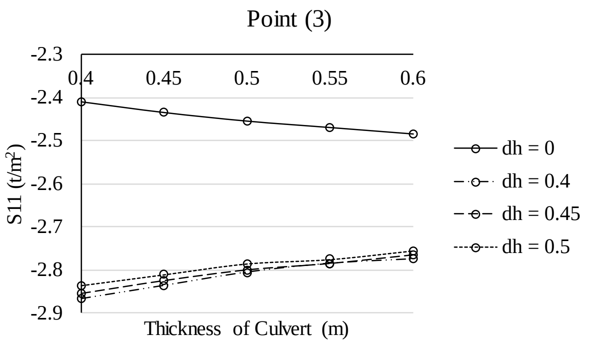


Figure 3c. S11 at point (3) for case b = 6 m.

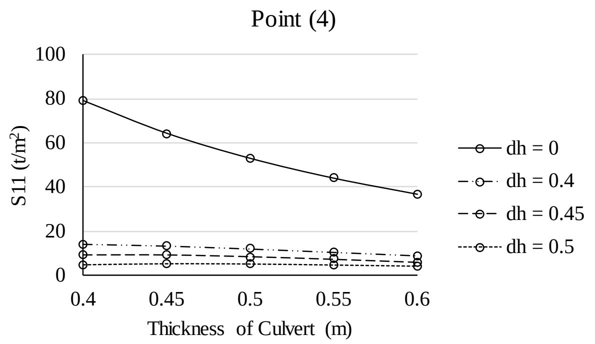


Figure 3d. S11 at point (4) for case b = 6 m.

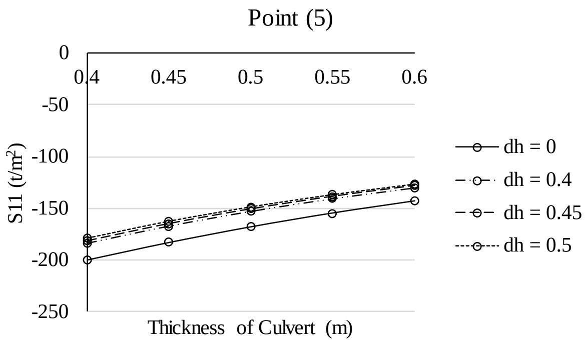


Figure 3e. S11 at point (5) for case b = 6 m.

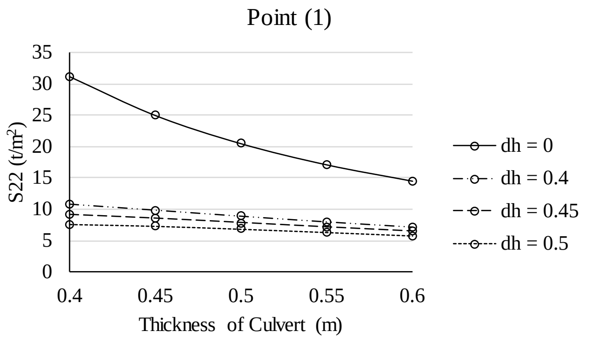


Figure 4a. S22 at point (1) for case b = 6 m.

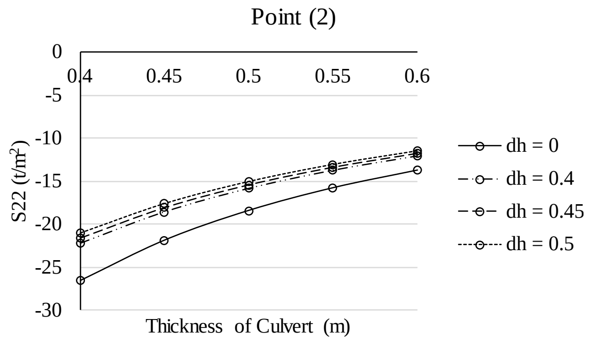


Figure 4b. S22 at point (2) for case b = 6 m.

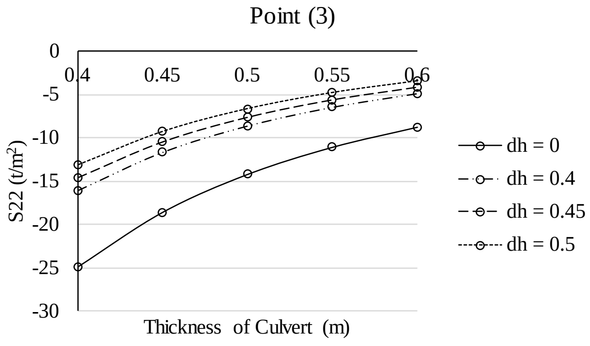


Figure 4c. S22 at point (3) for case b = 6 m.

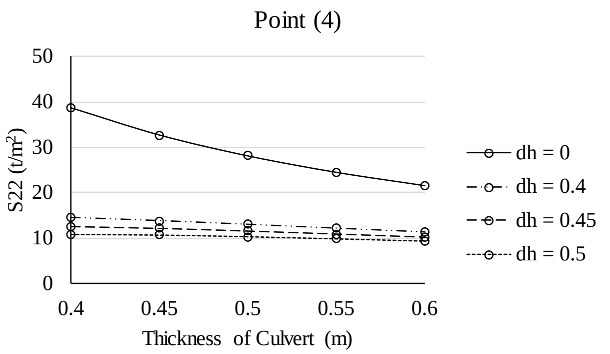


Figure 4d. S22 at point (4) for case b = 6 m.

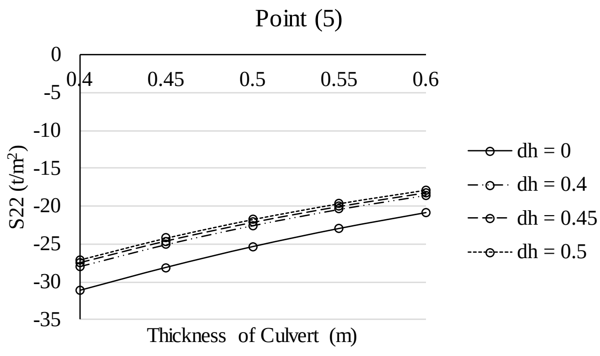


Figure 4e. S22 at point (5) for case b = 6 m.

Figures 3a–3e, show the relationship between the thickness of culvert and dimensions of haunch for S11 at points 1–5. When the thickness of culvert increases by 12.5% of the original culvert thickness, the stress S11 decreases by an average 9.99%, 13.22%, 0.38%, 10.44% and 8.25% at the points respectively. All these values are computed for dimensions of haunch varies from 0 cm to 50 cm. When the dimensions of haunch increase by 12.5% of the original culvert thickness, the stress S11 decreases by an average of 19.95%, 2.32%, 0.37%, 34.93% and 1.4% at the points respectively. All these values are computed for the thickness of culvert varies from 40 cm to 60 cm.

Table 1. Ratio between stress S11 without haunch and with 40 cm haunch for b = 6 m.

S11	t = 0.4	t = 0.45	t = 0.5	t = 0.55	t = 0.6
P (1)	75.06%	70.90%	67.50%	64.68%	62.39%
P (2)	15.74%	14.53%	13.5%	12.61%	11.82%
P (3)	−18.9%	−16.3%	−14.3%	−12.8%	−11.7%
P (4)	81.88%	79.09%	77.28%	76.32%	76.18%
P (5)	8.03%	8.66%	8.93%	8.99%	8.93%

Figures 4a–4e, show the relationship between the thickness of culvert and dimensions of haunch for S22 at points 1–5. When the thickness of culvert increases by 12.5% of the original culvert thickness, the stress S22 decreases by an average of 10.39%, 14.3%, 26.02%, 7.88% and 9.8% at the points respectively. All these values are computed for dimensions of haunch varies from 0 cm to 50 cm. When the dimensions of haunch increases by 12.5% of the original culvert thickness, the S22 decreases by an average 12.82%, 2.46%, 12.23%, 11.14% and 1.79% at the

points respectively. All these values are computed for the thickness of culvert varies from 40 cm to 60 cm.

Table 2. Ratio between stress S22 without haunch and with 40 cm haunch for b = 6 m.

S22	t = 0.4	t = 0.45	t = 0.5	t = 0.55	t = 0.6
P (1)	65.21%	60.38%	56.30%	52.92%	50.10%
P (2)	16.39%	15.15%	14.08%	13.06%	12.28%
P (3)	35.60%	37.43%	39.49%	41.84%	44.50%
P (4)	62.27%	57.61%	53.73%	50.51%	47.78%
P (5)	10.21%	10.78%	10.97%	11.00%	10.91%

Table 3. Difference for an amount of concrete for cases with and without haunch for b = 6 m.

	t = 0.4	t = 0.45	t = 0.5	t = 0.55	t = 0.6
Dh = 0.40	2.17%	2.06%	1.96%	1.87%	1.79%
Dh = 0.45	2.74%	2.60%	2.47%	2.35%	2.25%
Dh = 0.50	3.36%	3.18%	3.03%	2.89%	2.76%

From Tables 1 and 2, we can find that introducing a 40 cm haunch decreases the values of S11 and S22 by an average 68.11% and 56.98% for point (1), 78.15% and 54.38% for point (4), while the average reduction is 13.64% and 14.19% for point (2), 8.71% and 10.77% for point (5). From Table 3, the maximum difference in concrete quantities is 3.36% between case without hunch and case with the 50 cm hunch.

- Case b = 5.5 m

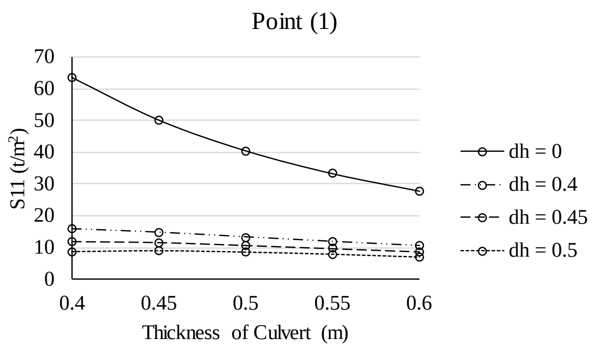


Figure 5a. S11 at point (1) for case b = 5.5 m.

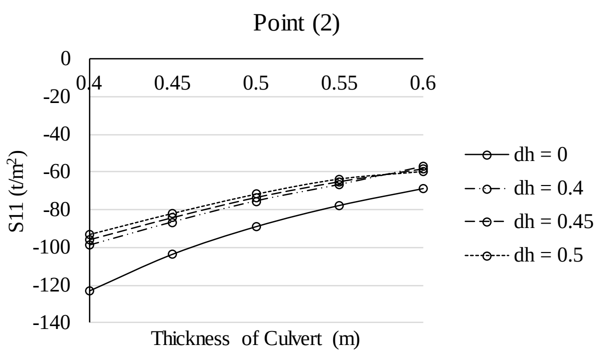


Figure 5b. S11 at point (2) for case b = 5.5 m.

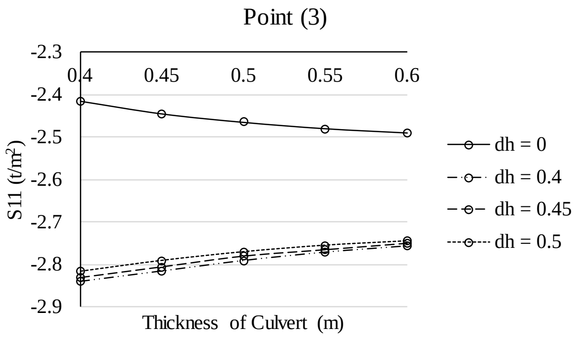


Figure 5c. S11 at point (3) for case b = 5.5 m.

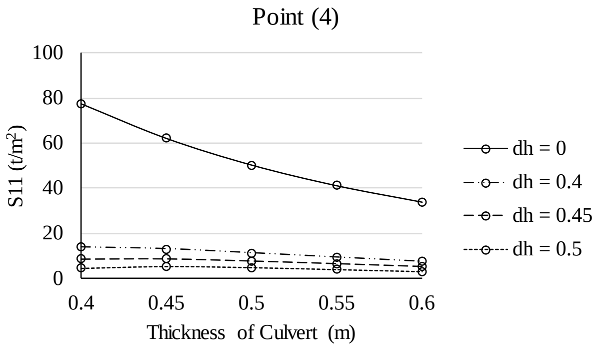


Figure 5d. S11 at point (4) for case b = 5.5 m.

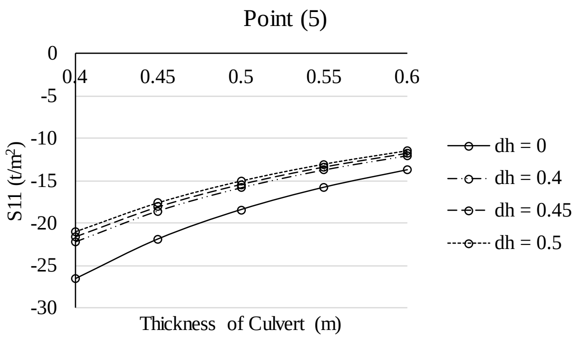


Figure 5e. S11 at point (5) for case b = 5.5 m.

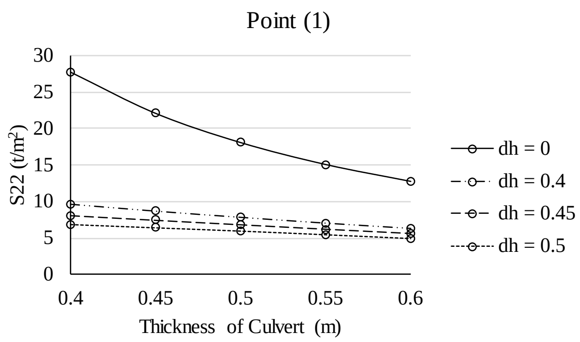


Figure 6a. S22 at point (1) for case b = 5.5 m.

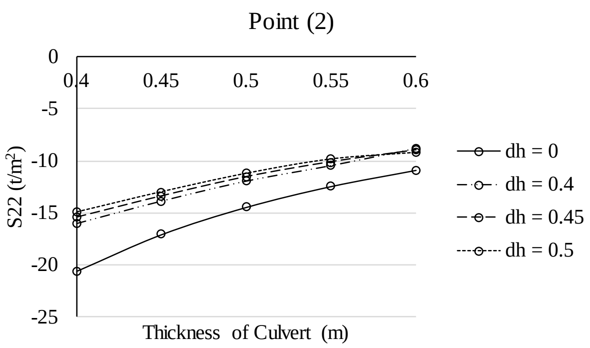


Figure 6b. S22 at point (2) for case b = 5.5 m.

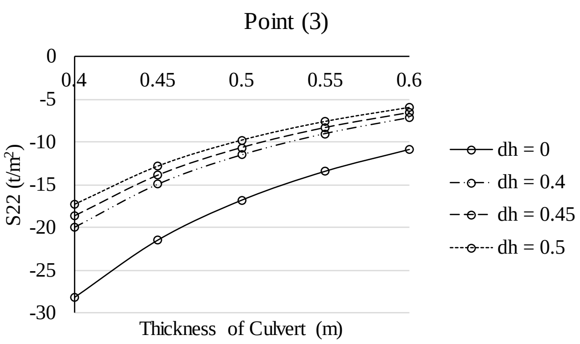


Figure 6c. S22 at point (3) for case b = 5.5 m.

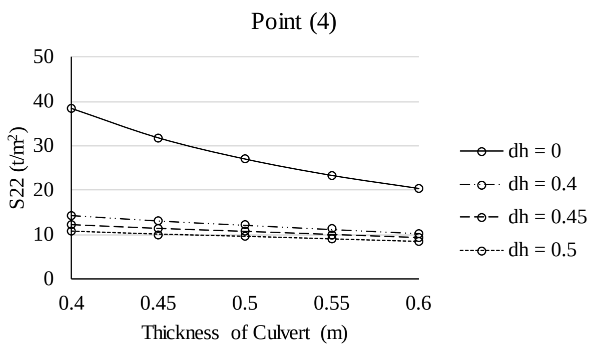


Figure 6d. S22 at point (4) for case b = 5.5 m.

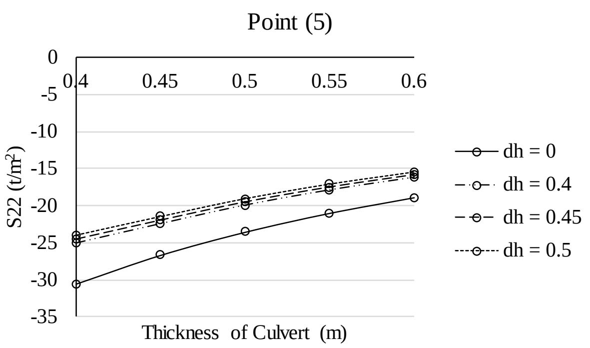


Figure 6e. S22 at point (5) for case b = 5.5 m.

Table 4. Ratio between stress S11 without haunch and with 40 cm haunch for b = 5.5 m.

S11	t = 0.4	t = 0.45	t = 0.5	t = 0.55	t = 0.6
P (1)	75.13%	70.67%	67.31%	64.57%	62.34%
P (2)	19.72%	16.41%	15.11%	13.98%	16.70%
P (3)	−17.6%	−15.1%	−13.2%	−11.7%	−10.6%
P (4)	82.18%	78.98%	77.44%	76.85%	77.21%
P (5)	14.23%	12.35%	11.86%	11.36%	10.87%

Table 5. Ratio between stress S22 without haunch and with 40 cm haunch for b = 5.5 m.

S22	t = 0.4	t = 0.45	t = 0.5	t = 0.55	t = 0.6
P (1)	65.30%	60.79%	56.87%	53.67%	51.02%
P (2)	22.29%	18.87%	17.46%	16.18%	19.38%
P (3)	29.06%	30.27%	31.26%	32.40%	33.64%
P (4)	62.72%	58.64%	54.78%	51.59%	48.94%
P (5)	17.84%	15.70%	15.18%	14.64%	14.16%

Table 6. Difference for an amount of concrete for cases with and without haunch for b = 5.5 m.

	t = 0.4	t = 0.45	t = 0.5	t = 0.55	t = 0.6
Dh = 0.40	2.23%	2.12%	2.02%	1.93%	1.85%
Dh = 0.45	2.81%	2.67%	2.55%	2.43%	2.33%
Dh = 0.50	3.45%	3.28%	3.13%	2.99%	2.86%

Figures (5a–5e) show the relationship between the thickness of culvert and dimensions of haunch for S11 at points 1–5. When the thickness of culvert increases by 12.5% of the original culvert thickness, the S11 decreases by an average 10.07%, 12.2%, 0.33%, 12.75% and 8.91% at the points respectively. All these values are computed for dimensions of haunch varies from 0 cm to 50 cm. When the dimensions of haunch increases by 12.5% of the original culvert thickness, the S11 decreases by an average 20.29%, 1.65%, 0.34%, 36.91% and 1.73% at the points respectively. All these values are computed for the thickness of culvert varies from 40 cm to 60 cm.

Figures (6a–6e) show the relationship between the thickness of culvert and dimensions of haunch for S22 at points 1–5. When the thickness of culvert increases by 12.5% of the original culvert thickness, the S22 decreases by an average 11.08%, 13.18%, 22.59%, 8.7% and 10.58% at the points respectively. All these values are computed for dimensions of haunch varies from 0 cm to 50 cm. When the dimensions of haunch increases by 12.5% of the original culvert thickness, the S22 decreases by an average 12.87%, 1.93%, 7.93%, 11.4% and 2.3% at the points respectively. All these values are computed for the thickness of culvert varies from 40 cm to 60 cm.

From Tables 4 and 5, the effect of 40 cm haunch decreases the values of S11 and S22 by an average 68% and 57.23% for point (1), 78.53% and 55.34% for point (4). While the average is 16.38% and 18.84% for point (2), 12.14% and 15.5% for point (5). From Table (6), we can find that the maximum difference for concrete is 3.45% between case without hunch and case with the 50 cm hunch.

- Case c = 5 m

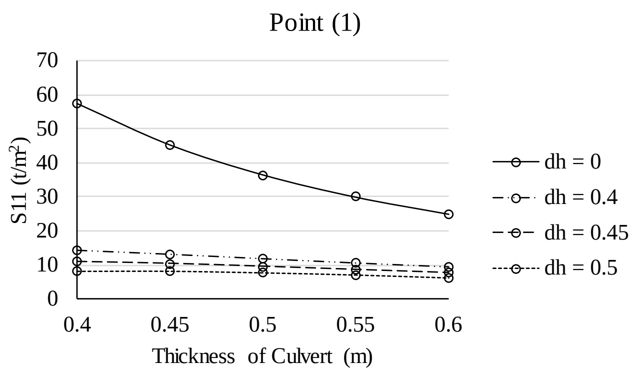


Figure 7a. S11 at point (1) for case b = 5 m.

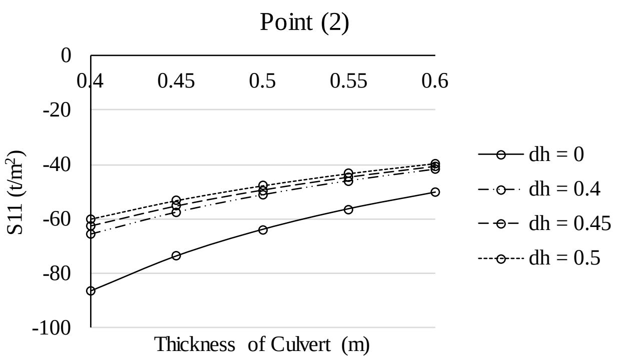


Figure 7b. S11 at point (2) for case b = 5 m.

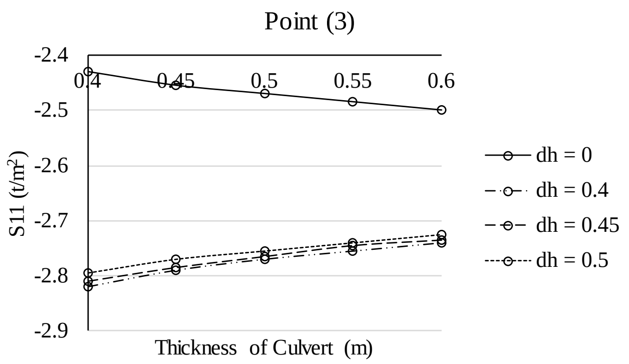


Figure 7c. S11 at point (3) for case b = 5 m.

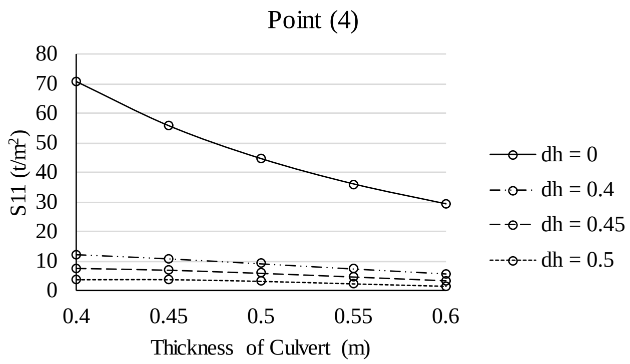


Figure 7d. S11 at point (4) for case b = 5 m.

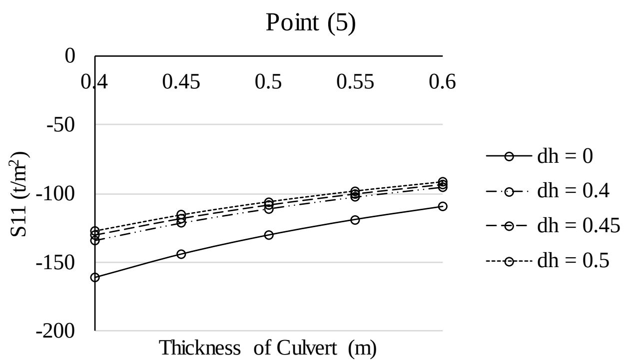


Figure 7e. S11 at point (5) for case b = 5 m.

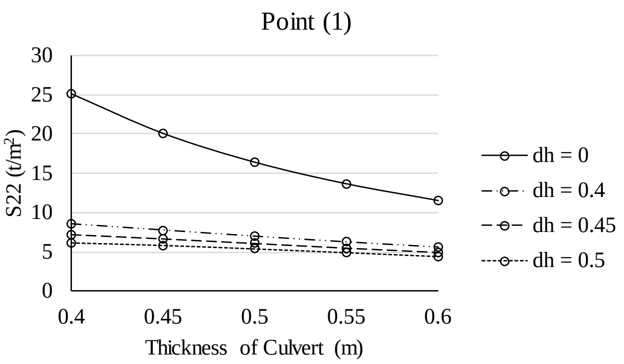


Figure 8a. S22 at point (1) for case b = 5 m.

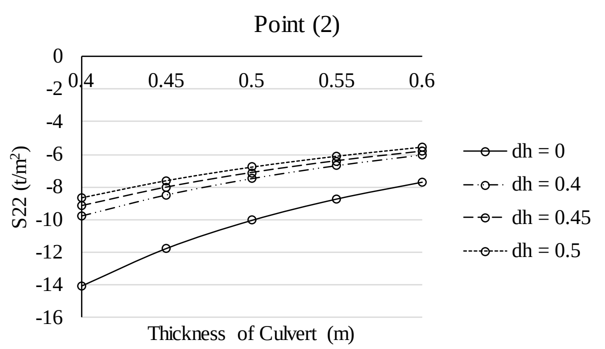


Figure 8b. S22 at point (2) for case b = 5 m.

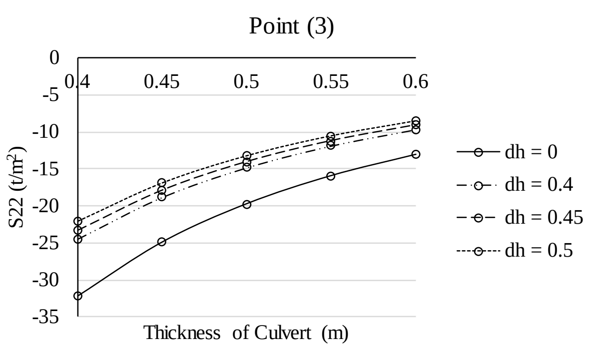
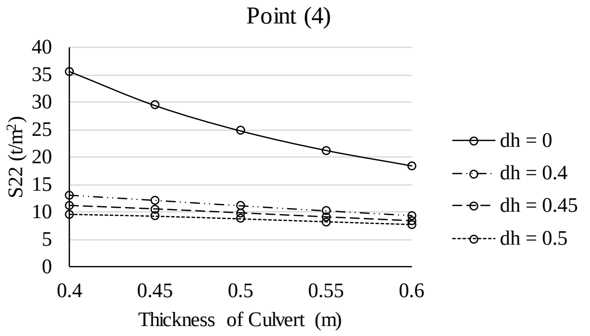


Figure 8c. S22 at point (3) for case b = 5 m.



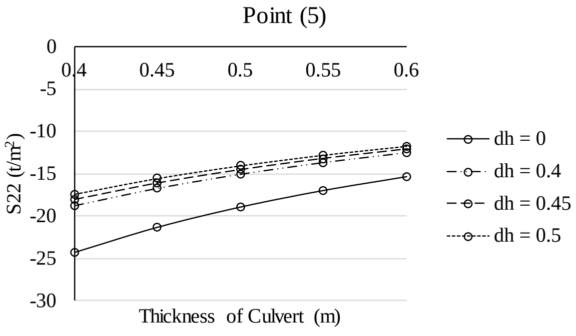


Figure 8d. S22 at point (4) for case b = 5 m.

Figure 8e. S22 at point (5) for case b = 5 m.

Table 7. Ratio between stress S11 without haunch and with 40 cm haunch for b = 5 m.

S11	t = 0.4	t = 0.45	t = 0.5	t = 0.55	t = 0.6
P (1)	74.84%	70.83%	67.56%	64.88%	62.71%
P (2)	24.37%	21.98%	19.97%	18.25%	16.79%
P (3)	−16.1%	−13.6%	−12.2%	−10.9%	−9.60%
P (4)	82.53%	80.74%	79.49%	79.59%	80.77%
P (5)	16.78%	15.77%	14.81%	13.93%	13.14%

Table 8. Ratio between stress S22 without haunch and with 40 cm haunch for b = 5 m.

S22	t = 0.4	t = 0.45	t = 0.5	t = 0.55	t = 0.6
P (1)	65.83%	61.27%	57.52%	54.42%	51.86%
P (2)	30.58%	27.94%	25.60%	23.57%	21.89%
P (3)	24.09%	24.45%	24.89%	25.45%	26.04%
P (4)	63.52%	55.03%	55.35%	52.23%	49.65%
P (5)	22.64%	21.51%	20.46%	19.47%	18.60%

Table 9. Difference for an amount of concrete for cases with and without haunch for b = 5 m.

	t = 0.4	t = 0.45	t = 0.5	t = 0.55	t = 0.6
Dh = 0.40	2.30%	2.19%	2.09%	2.00%	1.91%
Dh = 0.45	2.89%	2.75%	2.63%	2.51%	2.41%
Dh = 0.50	3.55%	3.38%	3.23%	3.09%	2.96%

Figures (7a–7e) show the relationship between the thickness of culvert and dimensions of haunch for S11 at points 1–5. When the thickness of culvert increases by 12.5% of the original culvert thickness, the S11 decreases by an average 10.71%, 10.83%, 0.33%, 18.72% and 8.33% at the points respectively. All these values are computed for dimensions of haunch varies from 0 cm to 50 cm. When the dimensions of haunch increases by 12.5% of the original culvert thickness, the S11 decreases by an average 20.36%, 3.51%, 0.32%, 42.74% and 2.27% at the points respectively. All these values are computed for the thickness of culvert varies from 40 cm to 60 cm.

Figures (8a–8e) show the relationship between the thickness of culvert and dimensions of haunch for S22 at points 1–5. When the thickness of culvert increases by 12.5% of the original culvert thickness, the S22 decreases by an average 11.15%, 11.59%, 20.68%, 8.94% and 9.91% at the points respectively. All these values are computed for dimensions of haunch varies from 0 cm to 50 cm. When the dimensions of haunch increases by 12.5% of the original culvert thickness, the S22 decreases by an average 12.84%, 4.79%, 5.59%, 11.33% and 3.33% at the points respectively. All these values are computed for the thickness of culvert varies from 40 cm to 60 cm.

From Tables 7 and 8, we can find that the effect of 40 cm haunch decreases the values of S11 and S22 by an average 68.16% and 58.18% for point (1). 80.57% and 55.69% for point (4). While the average is 20.27% and 25.91% for point, (2), 14.89% and 20.53% for point (5). From Table (9), we can find that the maximum difference for concrete is 3.55% between case without hunch and case with the 50 cm hunch.

- Effect of width of culvert.

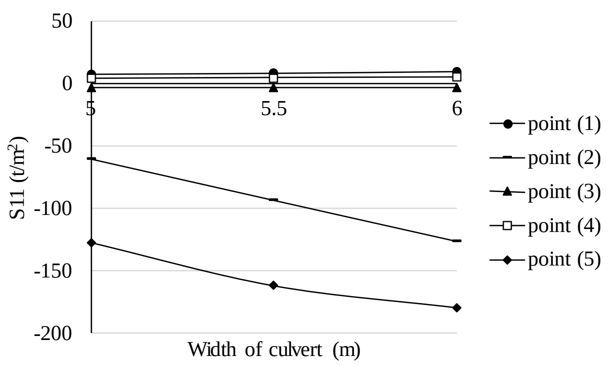


Figure 9a. S11 for case t = 0.4 m & dh = 0.5 m.

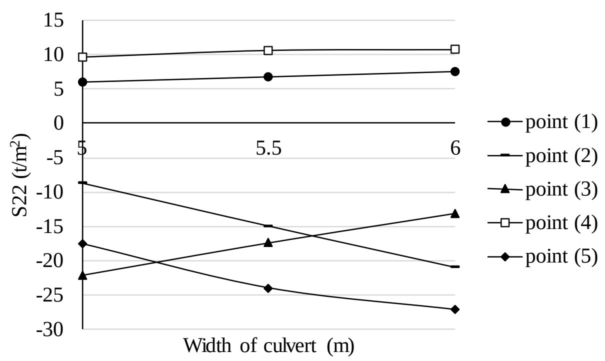


Figure 9b. S22 for case t = 0.4 m & dh = 0.5 m.

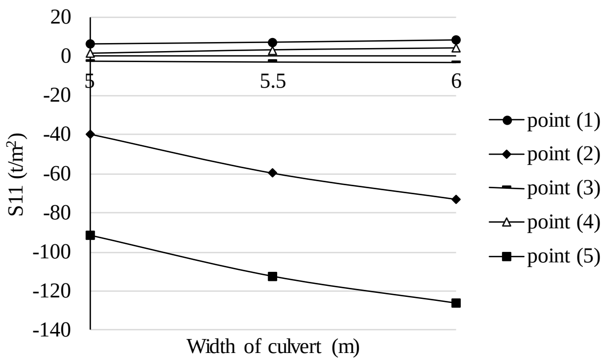


Figure 10a. S11 for case t = 0.6 m & dh = 0.5 m.

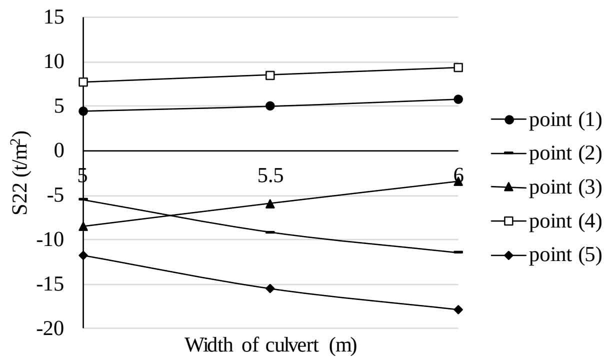


Figure 10b. S22 for case t = 0.6 m & dh = 0.5 m.

Figures (9a and 9b) show the relationship between the width of culvert and S11, S22 for thickness = 0.4 m and depth of haunch = 0.5 m at points 1–5. When the width of culvert increases by 10% of the original culvert width, the S11 increases by an average 11.44%, 28.5%, 0.6%, 23.8% and 15.24% at the points respectively. Also, the S22 increases by an average 11.65%, 32.6%, 7.48% and 19.15% at the points (1, 2, 4 and 5) except point (3) the S22 decreases by an average 43.47%.

5. Discussion

I did not find the published paper deals with effect of the haunch. In this study, three main parameters were investigated (width of the culvert, the thickness of the section and dimensions of haunch) to calculate stresses on the culvert. From the section of results, we found that stresses decreased by the increase of the thickness of the section because increase the moment of inertia of the section and the value of stresses divided by moment of inertia. Also, by the same reason, the stresses decreased by the increase of the dimension of the hunch. Although, the increasing of the two parameters reduces stresses but from the economic point of view, the haunch is the best because it needs a lesser amount of concrete. The third parameter is the width of the culvert make an inverse role for reduction of stresses because when it increases means that the load is increased so the internal forces increase then stresses will be increases. When a practicing engineer uses the findings of the study in design practice, I recommended him to use 40 cm hunch.

6. Summary and conclusions

For case b = 6 m, at the corners of the culvert when the thickness of the culvert and the dimensions of haunch increases by 12.5% of the original culvert thickness for each one, the S11 decreases by an average 10.22% and 27.45%, respectively, also the S22 decreases by an average 8.68% and 11.98%, respectively. Similarly, in the mid-span of the culvert, the S11 decreases by an average 7.29% and 1.36%, respectively, besides, the S22 decreases by an average 16.7% and 5.49%, respectively.

For case b = 5.5 m, at the corners of the culvert when the thickness of the culvert and the dimensions of haunch increases by 12.5% of the original culvert thickness for each one, the S11 decreases by an average 11.41% and 28.6%, respectively, also the S22 decreases by an average 12.13% and 11.98%, respectively. Similarly, in the mid-span of the culvert, the S11 decreases by an average 7.15% and 1.24%, respectively, besides, the S22 decreases by an average 15.45% and 4.05%, respectively.

For case b = 5 m, at the corners of the culvert when the thickness of the culvert and the dimensions of haunch increases by 12.5% of the original culvert thickness for each one, the S11 decreases by an average 14.71% and 31.55%, respectively, also the S22 decreases by an average 10.04% and 12.08%, respectively. Similarly, in the mid-span of the culvert, the S11 decreases by an average 6.49% and 2.03%, respectively, in addition, the S22 decreases by an average 14.06% and 4.57%, respectively.

Comparison between an amount of extra concrete for 40 cm haunch and increasing by 12.5% of the thickness of the culvert = 1: 2.78.

The presence of 40 cm haunch leads to decreases in stresses with an average of 40%.

Increasing 12.5% of the dimensions of haunch decreases the values of stresses by an average of 12%.

The increasing 12.5% of the thickness of the culvert decreases the values of stresses by an average of 10.75%.

Effect of increasing 12.5% of dimensions of haunch increase the percentage of an amount of concrete by an average of 3.46%.

Increasing of 10% of the width of culvert increases the values of stresses by an average of 10.7%.

The effect of the hunch on the small thickness of the sector is better than the effect on the large thickness of the sector in reducing stresses.

The presence of haunch is the best solution for decreasing the values of stresses from the economic point of view.

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Conflict of Interest

The author declares that there is no conflict of interest regarding the publication of this paper.

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