Research on Calculating Formula of Self-Weight of Column-Supported Space Truss

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Abstract. With the rapid development of steel structure engineering in China, grid structure has been widely used. For the self-weight of space truss, the current regulations give the corresponding calculation formula, but in practical engineering applications, it is found that the calculation formula for column-supported space truss has poor adaptability. Therefore, in this paper, the adaptability of the formula is analyzed according to the current self-weight calculation formula for cylindrical point supported space truss, and the self-weight estimation of the space truss is revised on the basis of statistics and regression analysis. The formula modification can improve the applicability of the grid estimation formula, and also provide some reference for the revision of relevant codes and regulations.

Keywords. Column support, deadweight calculation, correction coefficient.

1. Introduction

1.1. About the Weight of the Grid

The weight of the grid is the weight of the grid itself, which is a constant load in nature. The weight of the grid consists of two parts: the weight of the rod and the weight of the node. The grid bolt ball joint is composed of bolts, steel balls, screws, sleeves, etc. Most of the rod material of the grid is made of steel. Estimating the weight of the grid plays an important role in the selection of the grid structure and budget control. The current industry regulations “Technical Regulations for Space Grid Structures” (JGJ7-2010) stipulate that the self-weight can be calculated according to the following formula: where the standard value of the grid’s self-heavy load; the roof load other than the grid’s own weight or the standard value of the floor load (KN/m); the short span of the L2-grid (m). However, in practical engineering applications, it is found that the calculation formula has relatively good applicability to the surrounding support grid, and the applicability to the pillar support grid is poor. Therefore, the calculated result according to the formula has a large deviation from the actual one.

After reviewing the references on the research of grid weights in the past 20 years, only a few scholars in the early stage have studied the estimation formula of the grid’s own weight, and proposed the corresponding correction formula correction coefficient. More representative of the Xuzhou Mining Bureau Qiang was published in “Xu Coal Science and Technology” in 1993. “Progress on the value of the coefficient of the self-weight estimation of welded steel pipe grid” and Professor Chen Zihua of Tianjin University published in “Space Structure” magazine in 2005. Two papers on the study of structural self-weight estimation formula, the former proposed the recommendation that the coefficient in the self-weight estimation formula should be mentioned from 1.0 to 1.6 [1], and the latter respectively have a total of 400 grid construction drawings for the square pyramid and the oblique pyramid. After statistical analysis and regression, the parameter values with 95% guarantee
rate and the relationship between parameter values and short-span span under various loads are obtained. Based on statistical and regression analysis, the self-weight estimation of the grid is obtained. Correct the formula [2]. Since then, in the past 15 years, basically no scholars have studied the weight of the grid.

According to the needs of practice, it is necessary to carry out further in-depth research on the estimation of the weight of the grid. By correcting the estimation formula of the grid’s own weight, it can not only improve the accuracy and application range of the grid calculation formula, but also provide a reference for the revision of relevant specifications and procedures.

2. Adaptability Analysis of Self-weight Calculation Formula for 2 Column Point Support Grid Structure

2.1. Analysis of Grid Weight and Deviation Data
In this paper, the construction drawing data of 16 sets of column-supported grids are counted, and the statistical data is summarized and analyzed. The measured values of the dead weight of each grid and the estimated values according to the norm formula are calculated. The comparison results are shown in the table 1.

According to table 1, there are two characteristics between the standard value of the self-heavy load of the grid calculated by the standard formula and the measured value of the self-weight of the grid. First, the deviation between the two is large, and the second is that the deviation is positive or negative. According to statistical analysis, only 3 deviations in the 18-column support grid are within ±5%, 2 deviations are within ±10%, 0 deviations are within ±20%, and 2 deviations are within ±30. Within 4%, there are 4 deviations within ±50%, and the deviation of 5 grids exceeds ±50%, of which 1 deviation exceeds ±100%, and the maximum deviation even reaches 104%. The data show that the calculated value of the self-weight of the column-supported grid obtained by the standard formula has a large deviation from the measured value, and the application effect is really poor. Does the formula have any correction value for the column-supporting grid and can be further used in engineering practice? Further research is needed.

2.2. Analysis of the Relationship between the Estimated Weight and the Deviation of the Grid
The net weight of the sample data is estimated as the x-axis, and the deviation between the estimated value and the measured value is the y-axis. The scatter plot of the estimated value and deviation of the grid’s own weight can be obtained (figure 1. Law: 1). With the increase of the estimated value of the grid’s own weight, the calculated deviation gradually changes from a negative value to a positive value. When the estimated self-weight value is 25-30kg/m², the deviation between the estimated value and the measured value is close to 0, which means the estimated value is in good agreement with the measured value; 2). When the estimated self-weight value is small, the deviation is negative, which means that the estimated value is smaller than the measured value. When the estimated value is large, the deviation is positive, which means estimation; 3) linear, logarithmic, quadratic polynomial, quadratic polynomial fitting is performed on the scatter data in the graph, and the R² values of the four fittings are between 0.550 and 0.600, and the fitting effect is generally.

2.3. Analysis of the Relationship between the Measured Weight and Deviation of the Grid
The measured self-weight value of the grid data of the sample data is the x-axis, and the deviation between the estimated value and the measured value is the y-axis, and the scatter plot of the measured value and deviation of the grid self-weight can be obtained (figure 2. Contents: 1) With the increase of the measured value of the self-weight of the grid, the calculation deviation gradually changes from a positive value to a negative value, that is, there is a tendency that the measured value is larger and the estimated value is smaller; 2) when the measured self-weight value is small, the deviation is Positive value means that the estimated value is larger than the measured value. When the estimated value is large, the deviation is negative, which means that the estimated value is smaller than the measured
value; 3) linear, logarithmic, the $R^2$ values of the four fittings are all around 0.550, and the fitting effect is general.

**Table 1.** The measured value and estimated value of the self-weight of the column support grid.

| No | Name | Structure form | Plane Size/m | Thickness/m | Roof load standard value (kN/m²) | Grid frame dead weight (kg/m²) | According to the standard calculation of self-weight estimation (kg / m²) | Deviation |
|----|------|----------------|--------------|-------------|----------------------------------|--------------------------------|--------------------------------|-----------|
| 1  | Steel grid 1 | 34×10 | 3.018/4.2 | 1.10 | 19.97 | 6.99 | -65.10% |
| 2  | Steel grid 2 | 55×24 | 1.80/2.245 | 1.10 | 17.17 | 16.78 | -2.26% |
| 3  | Steel grid 3 | 21.7×20.8 | 1.8 | 1.50 | 24.04 | 16.98 | -29.37% |
| 4  | Steel grid 4 | 36.2×37.1 | 1.417/1.717 | 1.60 | 30.13 | 30.57 | 1.47% |
| 5  | Steel grid 5 | 200×50 | 1.5/2.164 | 0.70 | 15.93 | 21.89 | 37.41% |
| 6  | Steel grid 6 | 30×30 | 2.2/3.638 | 1.00 | 15.71 | 15.00 | -4.50% |
| 7  | Steel grid 7 | 52.5×40 | 2.02/2.5 | 1.00 | 18.59 | 26.67 | 43.48% |
| 8  | Steel grid 8 | 52.5×40 | 2.02/2.6 | 1.20 | 19.39 | 29.21 | 50.61% |
| 9  | Steel grid 9 | 65×56 | 2.02/2.7 | 1.00 | 25.12 | 37.33 | 48.60% |
| 10 | Steel grid 10 | Column point support | 29.6×64.5 | 1.3/2.065 | 1.00 | 18.61 | 19.73 | 6.02% |
| 11 | Steel grid 11 | 21×27 | 1.5 | 1.20 | 14.14 | 15.34 | 8.49% |
| 12 | Steel grid 12 | 28×35.8 | 1/1.519 | 1.20 | 15.82 | 20.45 | 29.27% |
| 13 | Steel grid 13 | 32×44 | 1/2.0 | 1.20 | 16.70 | 23.37 | 39.97% |
| 14 | Steel grid 14 | 33×36 | 1.5/2.078 | 1.20 | 15.96 | 24.10 | 51.00% |
| 15 | Steel grid 15 | 46.7×56.7 | 1.5/2.035 | 1.20 | 14.30 | 29.17 | 104.00% |
| 16 | Steel grid 16 | 44×73.3 | 2.4 | 1.20 | 20.66 | 32.12 | 55.50% |

Remarks: Deviation = (calculation of self-weight estimation according to the norm-actual measured weight of the grid) / actual measured value of the grid.
3. Study on Correction of Self-weight Estimation Formula of 3 Supporting Frame Structures

According to the research and analysis in the previous section, the calculation formula of the self-weight of the grid given by the current regulations is relatively large when applied to the column support grid. It is necessary to make appropriate corrections to improve the accuracy of the calculation of the self-weight. Therefore, the following is mainly to correct the self-weight estimation formula of the column support grid.

3.1. Pre-correction Sample Data and Processing

The original data of Table 1 is processed accordingly, and Table 2 is obtained, which provides data support for the subsequent correction of the self-weight estimation formula. Remarks: face thickness ratio \( m = \frac{\text{grid expansion area}}{\text{grid thickness}} \), self-weight deviation ratio \( n = \frac{\text{self-weight value}}{\text{actual weight value according to the specification}} \).

| No | Name     | Face ratio | thickness | Grid frame dead weight (kg/m²) | According to the standard calculation of self-weight estimation (kg/m²) | Gravity deviation ratio/ n |
|----|----------|------------|-----------|-------------------------------|---------------------------------------------------------------------|-----------------------------|
| 1  | Steel grid 1 | 80.95      | 19.97     | 6.99                          | 16.78                                                               | 0.35                        |
| 2  | Steel grid 2 | 587.97     | 17.17     | 16.98                         | 16.78                                                               | 0.98                        |
| 3  | Steel grid 3 | 250.76     | 24.04     | 30.57                         | 27.89                                                               | 1.01                        |
| 4  | Steel grid 4 | 783.27     | 30.13     | 15.93                         | 15.93                                                               | 1.37                        |
| 5  | Steel grid 5 | 4621.07    | 15.93     | 15.93                         | 15.93                                                               | 1.37                        |
| 6  | Steel grid 6 | 247.39     | 15.93     | 15.93                         | 15.93                                                               | 1.37                        |
| 7  | Steel grid 7 | 840.00     | 18.59     | 26.67                         | 26.67                                                               | 1.43                        |
| 8  | Steel grid 8 | 807.69     | 19.39     | 29.21                         | 29.21                                                               | 1.51                        |
| 9  | Steel grid 9 | 1348.15    | 23.33     | 37.33                         | 37.33                                                               | 1.60                        |
| 10 | Steel grid 10 | 924.55    | 18.61     | 19.73                         | 19.73                                                               | 1.06                        |
| 11 | Steel grid 11 | 378.00    | 14.14     | 15.34                         | 15.34                                                               | 1.08                        |
| 12 | Steel grid 12 | 659.91    | 15.82     | 20.45                         | 20.45                                                               | 1.29                        |
| 13 | Steel grid 13 | 704.00    | 16.70     | 23.37                         | 23.37                                                               | 1.40                        |
| 14 | Steel grid 14 | 571.70    | 15.96     | 24.10                         | 24.10                                                               | 1.51                        |
| 15 | Steel grid 15 | 1301.17   | 14.30     | 29.17                         | 29.17                                                               | 2.04                        |
| 16 | Steel grid 16 | 1343.83   | 20.66     | 34.09                         | 34.09                                                               | 1.65                        |

Compared with 1 group, there are 2 groups in which the self-weight deviation ratio ≤±10% in 16
3.2. Correction by Face Thickness Ratio

The weight of the grid is related to the load size, the support form, the span size and other factors. It is also related to the thickness of the grid and the grid size. In order to consider the influence of the thickness and span of the grid, this section introduces the thickness ratio \( f \) (\( f = \text{grid expansion area/grid thickness} \)). \( f \) is a dimensionless unit.

The scatter plot is plotted with the aspect ratio as the x-axis and the self-weight deviation ratio as the y-axis, as shown in Figure 3. Linear, exponential, logarithmic, polynomial, and power function fittings were performed on the data. The fitting results showed that the power function fitting result was slightly better, and the fitted \( R^2 = 0.610 \), indicating that the dispersion of the fitting data is still slightly biased. Big. According to the fitting result, the correction coefficient \( k = 0.044x^{0.511} \) (\( x \) is the face thickness ratio) can be obtained.

![Figure 3. Estimated value and deviation ratio of self-weight.](image)

![Figure 4. Self-weight deviation ratio after correction.](image)

In Table 3, the n/k values after considering the correction coefficient \( k \) and the corrected estimated values are calculated. Compared with 1, there are 5 sets of corrected self-weight deviation ratio \( \leq \pm 10\% \) in the 20 sets of data, \( \leq \pm \). There are 6 groups of \( 20\% \), 5 groups of \( \leq \pm 40\% \), and the data distribution is acceptable. The self-weight deviation ratio after correction is shown in Figure 4.

After calculation, the average value of 20 sets of n/k values was \( \mu_3 = 1.04 \), the standard deviation \( \sigma_3 = 0.19 \), and the coefficient of variation \( \varepsilon_3 = 0.18 \). Compared with the original self-weight deviation ratio, the average value of the data is basically in line with expectations, and the degree of dispersion of the data is significantly improved.

3.3. Determination and Application of Correction Factor

In addition to the above-mentioned aspect ratio correction method, other parameters such as self-weight estimation value, length-to-short span ratio, etc. are corrected. After comparison, the correction result according to the surface thickness ratio is relatively ideal, and other correction methods can also play a certain role. However, the discreteness of the data is still relatively large. Therefore, this paper suggests using the face thickness ratio to correct.

Combined with the calculation formula given by the procedure, the modified formula of the self-weight of the surrounding support grid is
### Table 3. Data after self-weight correction.

| No | Name           | Measured self-weight space of truss (kg/m²) | Face thickness ratio | Gravity deviation ratio/n | Correction coefficient/K | n/k | Measured self-weight of truss (kg/m²) |
|----|----------------|--------------------------------------------|----------------------|----------------------------|--------------------------|-----|---------------------------------------|
| 1  | Steel grid 1   | 6.99                                       | 80.95                | 0.35                       | 0.42                     | 0.83| 16.64                                 |
| 2  | Steel grid 2   | 16.78                                      | 587.97               | 0.98                       | 1.14                     | 0.86| 14.72                                 |
| 3  | Steel grid 3   | 16.98                                      | 250.76               | 0.71                       | 0.74                     | 0.96| 22.95                                 |
| 4  | Steel grid 4   | 30.57                                      | 783.27               | 1.01                       | 1.32                     | 0.77| 23.16                                 |
| 5  | Steel grid 5   | 27.89                                      | 4621.07              | 1.37                       | 1.04                     | 1.32| 26.82                                 |
| 6  | Steel grid 6   | 20.00                                      | 247.39               | 0.95                       | 0.74                     | 1.28| 27.03                                 |
| 7  | Steel grid 7   | 26.67                                      | 840.00               | 1.43                       | 1.37                     | 1.04| 19.47                                 |
| 8  | Steel grid 8   | 29.21                                      | 807.69               | 1.51                       | 1.35                     | 1.12| 21.64                                 |
| 9  | Steel grid 9   | 37.33                                      | 1348.15              | 1.6                        | 1.75                     | 0.91| 21.33                                 |
| 10 | Steel grid 10  | 19.73                                      | 924.55               | 1.06                       | 1.44                     | 0.74| 13.70                                 |
| 11 | Steel grid 11  | 15.34                                      | 378.00               | 1.08                       | 0.91                     | 1.19| 16.86                                 |
| 12 | Steel grid 12  | 20.45                                      | 659.91               | 1.29                       | 1.21                     | 1.07| 16.90                                 |
| 13 | Steel grid 13  | 23.37                                      | 704.00               | 1.4                        | 1.25                     | 1.12| 18.70                                 |
| 14 | Steel grid 14  | 24.10                                      | 571.70               | 1.51                       | 1.23                     | 1.23| 19.59                                 |
| 15 | Steel grid 15  | 34.32                                      | 1301.17              | 2.04                       | 1.73                     | 1.18| 19.84                                 |
| 16 | Steel grid 16  | 32.12                                      | 1343.83              | 1.65                       | 1.75                     | 0.94| 18.35                                 |

$$g_{ok} = \frac{\sqrt{q_k L_2}}{150k}$$  \hspace{1cm} (1)

where - in the standard value of the self-heavy load of the grid; - the standard value of the roof load or floor load (KN/m) except the weight of the grid; the short span of the L2-grid (m); the correction factor \( k = 0.044f0.511 \) (\( f \) is the aspect ratio).

### 4. Conclusions and Prospects

#### 4.1. Conclusion

Through the research of this paper, the main conclusions are as follows:

1. For the surrounding supporting grid, the standard deviation between the standard value of the grid and the measured value of the grid’s self-weight is calculated according to the standard formula. The application effect is not ideal. It is necessary to further study the given formula of the specification. And corrections to make it more consistent with engineering practice needs.

2. The correction coefficient of the self-weight estimation of the surrounding support grid is studied recently. Compared with the original self-weight deviation ratio, the average value of the data corrected by the self-weight estimation is in line with expectations, and the degree of data dispersion has also been significantly changed.

3. According to the calculation formula given by the procedure, the modified formula of the self-weight of the surrounding support grid is:

$$g_{od} = \frac{\sqrt{q_k L_2}}{150k}$$  \hspace{1cm} (2)

In the formula - the standard value of the self-heavy load of the modified grid; - the standard value of the roof load or floor load (KN/m) except the weight of the grid; the short span of the L2-grid (m); the correction factor \( k = 0.044f0.511 \) (\( f \) is the aspect ratio).
When applying the correction factor, the correction coefficient can be calculated according to the surface thickness ratio, and then brought into the equation (1) to obtain the corrected self-weight load estimation value.

4.2. Outlook
The research in this paper still has some shortcomings and needs to be further improved, as follows:

(1) The number of samples used for analysis in this paper is limited. If there are conditions in the future, the sample size of the analysis can be increased to further improve the accuracy of the analysis, and the research can be made more extensive.

(2) This paper only studies the self-weight estimation formula of the bolt-and-ball grid, which is not suitable for the welded ball grid. It is necessary to further study the adaptability of the self-weight estimation formula given in the welding ball grid.

References
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