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The Effect of Differential Settlement of Supports on a Large Steel-Framed Boiler Supporting Structure

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Abstract— The paper gives details of the distribution of forces induced in the members and variation of steel weight of an existing Boiler supporting structure, due solely to a vertical settlement of any column. The construction is described and typical frames were chosen and analyzed elastically. From this approach, a pattern appears to emerge, and it is hoped that this information will be of use to engineers engaged in the design of such structures on difficult sites where sizeable differential settlements may have to be accepted.

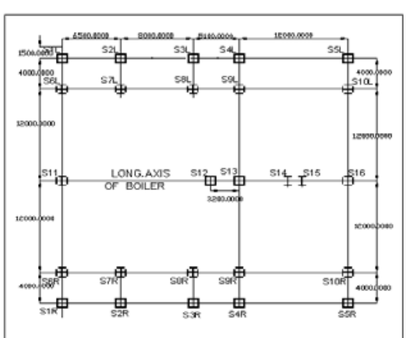
Index Terms— Differential settlement, distribution of forces induced.

THE PROBLEM

Generally supports are assumed to be restrained or immovable in analysis. However, they move, these movements produce a structural response. In addition to the displacement response, there also be a force response (additional internal forces and support reactions), which is a kind of indirect loading (secondary loading). Usually this type of loading occurs in addition to direct loading, and if not anticipated in design, may result in serious consequences. A structural engineer should be able to analyze the response (particularly, the force response) caused by such indirect loading. One of the sources of such indirect loading is support displacement and this is the problem which will be considered in more detail...

THE STRUCTURE

The boiler supporting structure is a steel structure consisting of columns, beams and Vertical bracing in both longitudinal and transverse directions along with horizontal floors at different levels. The dimensions of the structure are 32 m ×31.6 m in plan and 64.47m in height. The sections used for beams, columns and bracings are mild steel, and all the structural joints are simple joints (all moments released). The column bases are hinged. The typical frames chosen are shown in the fig (d), (e) and (f). Details of the plan and elevations are shown below.



BOILER KEY PLAN

Fig (a)

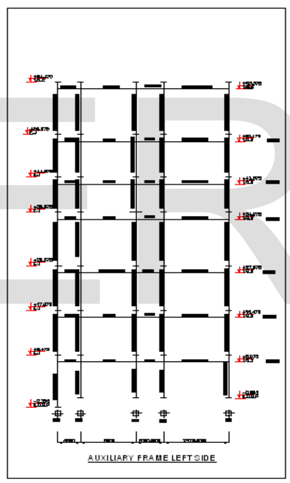


Fig (b)

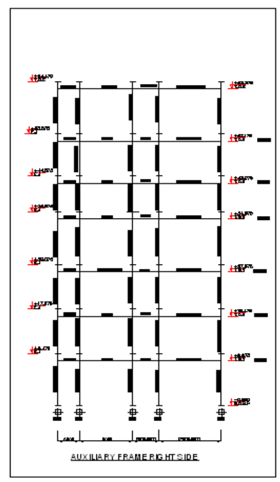


Fig (c)

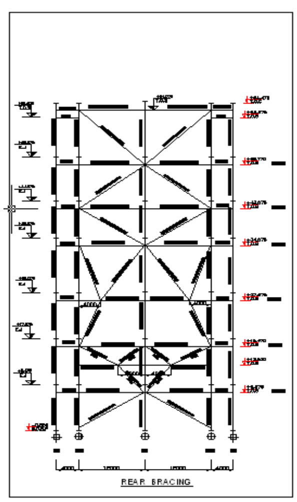


Fig (d)

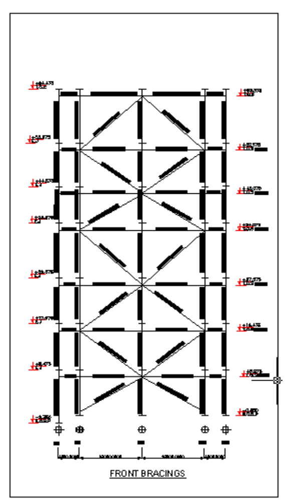


Fig (e)

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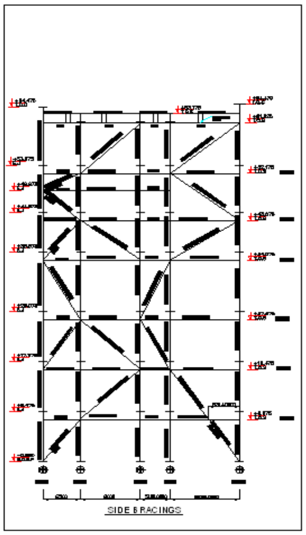


Fig (f)

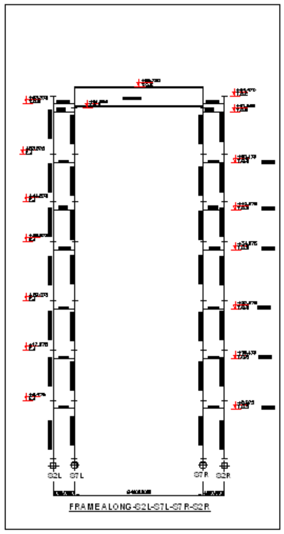


Fig (g)

METHODOLOGY

Initially, the structure has been analyzed by considering only secondary loads which were applied in the form of support displacements on supports of the critical frames chosen from the structure. After that, the structure has been again analyzed and redesigned by considering both primary and secondary loads due to settlement. The analysis and design has done by using STAAD.pro 2006.

The support displacement of magnitudes 2mm, 4mm, 6mm and 8mm were applied on the supports of the critical frames chosen from the structure. Totally, eight different cases were considered based on number of supports in the critical frames which are given below:

Case – 1

2mm, 4mm, 6mm and 8 mm settlement of support S6L

Case – 2

2mm, 4mm, 6mm and 8 mm settlement of support S7L

Case – 3

2mm, 4mm, 6mm and 8 mm settlement of support S8L

Case – 4

2mm, 4mm, 6mm and 8 mm settlement of support S9L

Case – 5

2mm, 4mm, 6mm and 8 mm settlement of support S13

Case – 6

2mm, 4mm, 6mm and 8 mm settlement of support S10L

Case – 7

2mm, 4mm, 6mm and 8 mm settlement of support S11

Case – 8

2mm, 4mm, 6mm and 8 mm settlement of support S16

RESULTS

The 250 MW fossil fuel boiler supporting structure has been analyzed and designed by considering all possible cases of secondary loads due to settlement of supports by using STAAD.pro 2006 and the results such as support reactions of the columns, variation of axial forces in the columns and the variation of steel weight of the structure will be given graphically for critical cases.

1. The axial loads induced in the beams were very small indeed and therefore could be neglected;
2. The axial loads induced in the columns were significant and could be either compressive or tensile;
3. The variation of support reactions of all columns in the critical frame are linear from 2mm to 8mm settlement for 2mm scale;
4. The weight of the steel was increased after considering the secondary loads due to settlement.

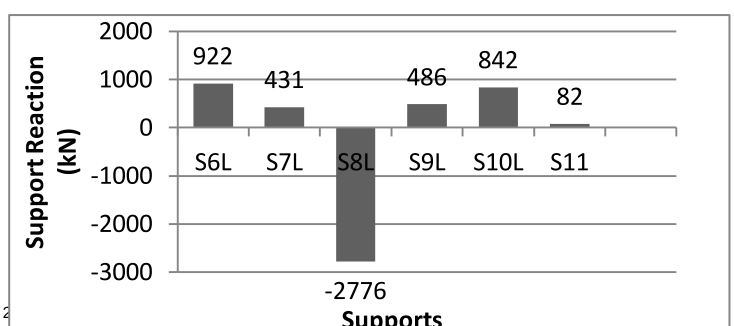
Thus three diagrams were drawn for each loading case, showing the pattern of

1. Distribution of axial loads induced in the columns;
2. Variation of support reaction in the columns; and
3. Variation of steel weight of the structure.

These results are shown in the following figures, for critical loading case.

1. SUPPORT REACTIONS

The following graphs shows the support reactions induced in various columns due to 8mm settlement in different load cases



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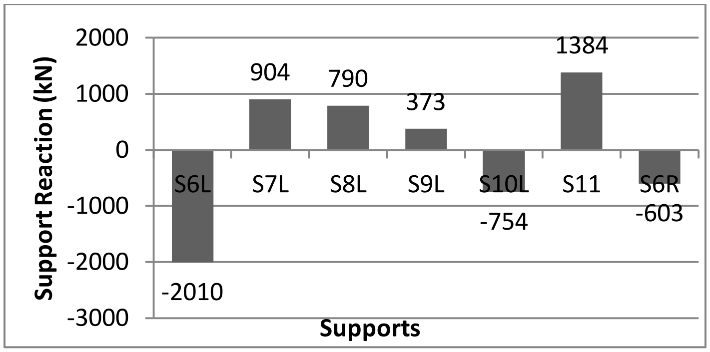

Fig 1 case – 1

Fig 2 case – 2

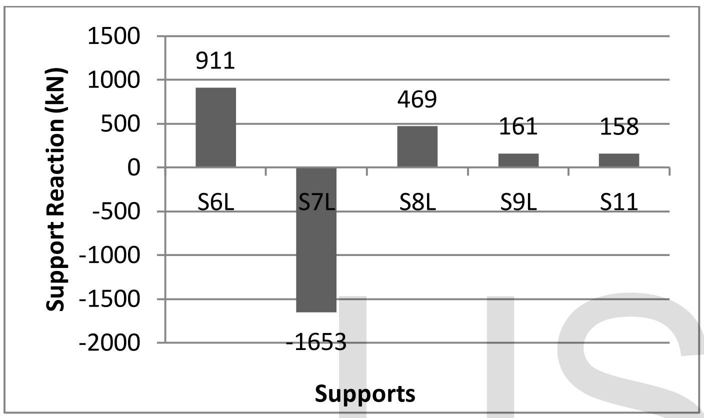

Fig 3 case – 3

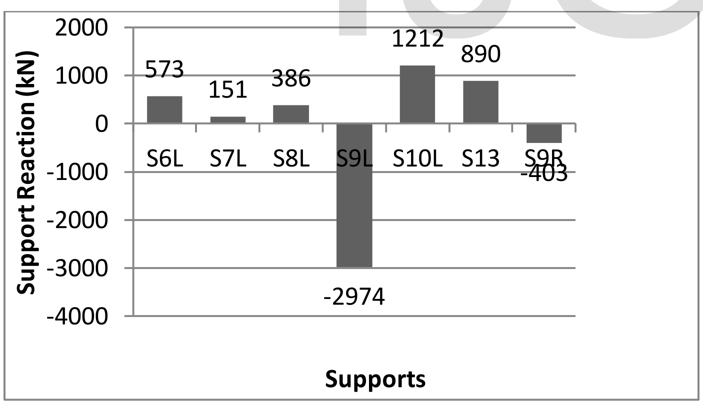

Fig 4 cases – 4

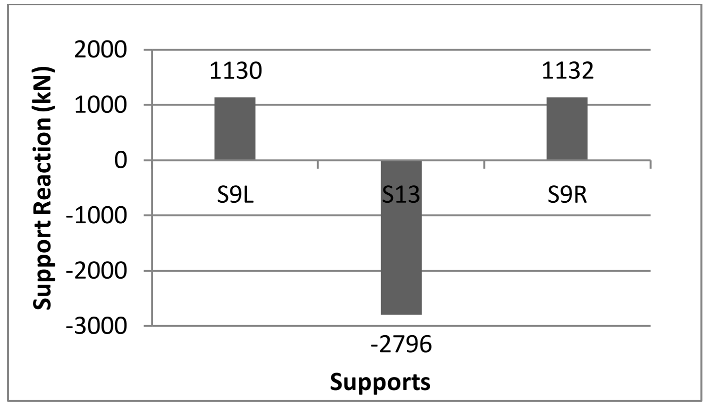

Fig 5 case – 5

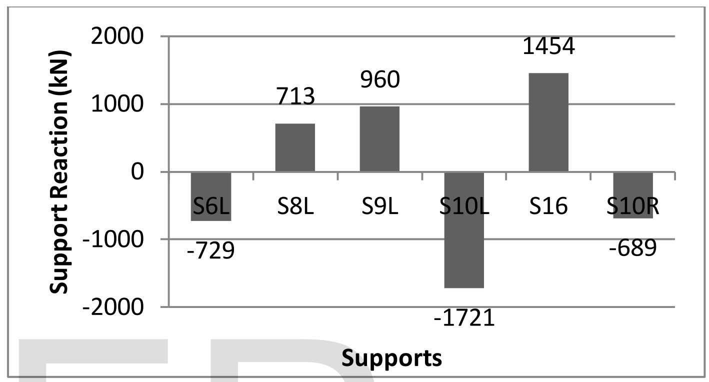

Fig 6 cases – 6

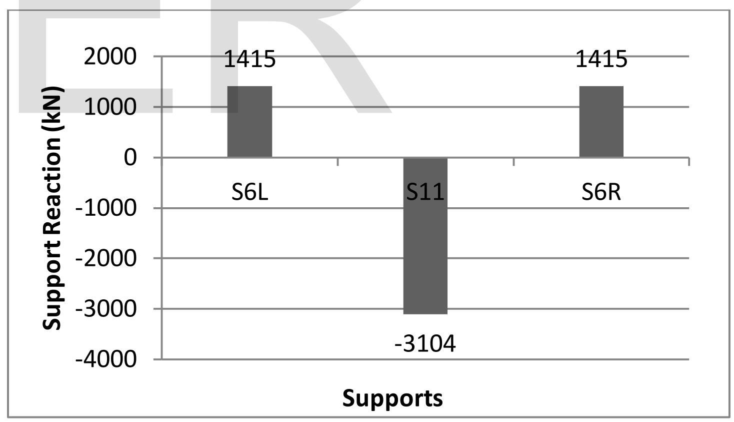

Fig 7 case –7

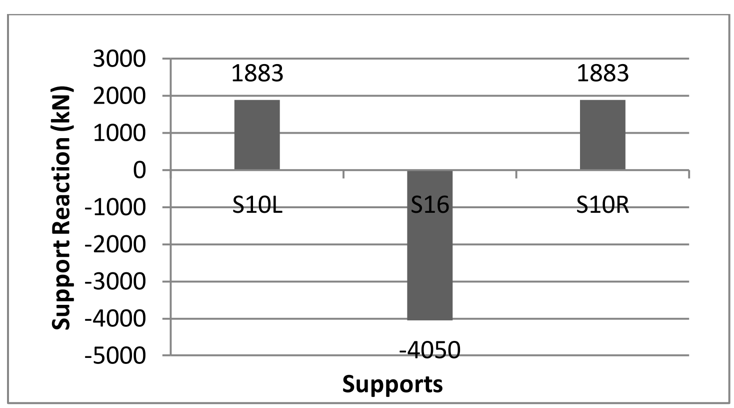

Fig 8 cases – 8

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2 Distribution of Axial Loads

The following graphs show the distribution of axial loads induced in the columns due to 8mm settlement in load case – 1.The distribution of axial force for remaining cases also similar to case – 1.

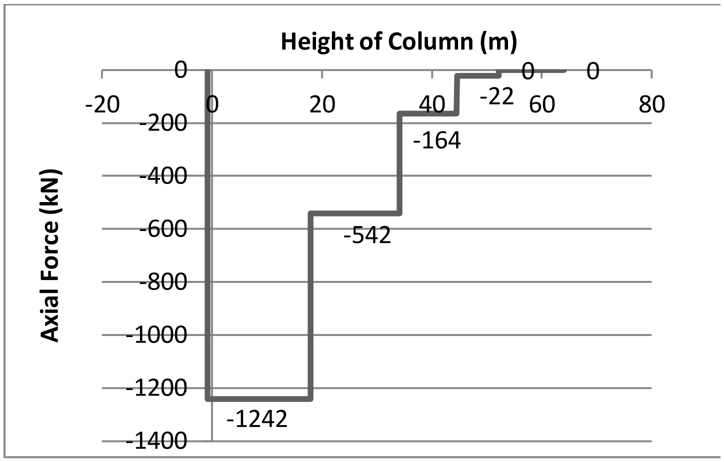

Fig 9 Distribution of axial load in column S6L

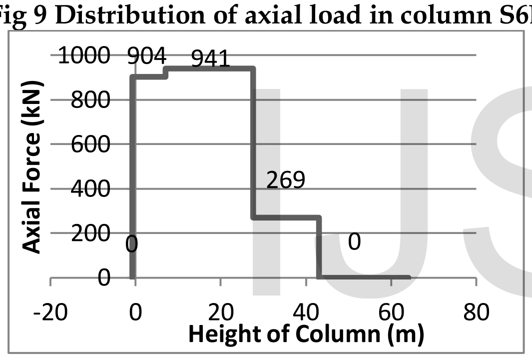

Fig 10 Distribution of axial load in column S7L

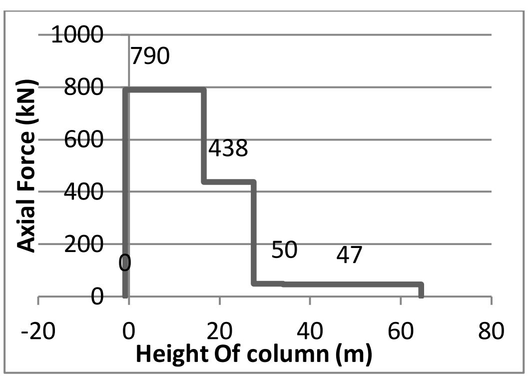

Fig 11 Distribution of axial load in column S8L

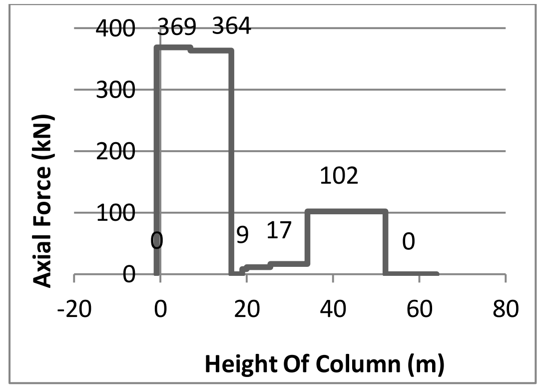

Fig 12 Distribution of axial load in column S9L

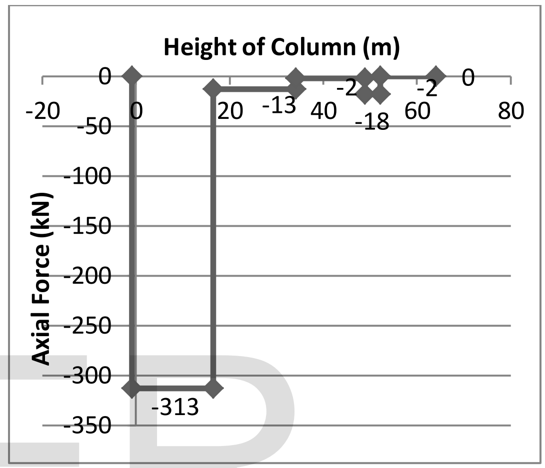

Fig 13 Distribution of axial load in column S6R

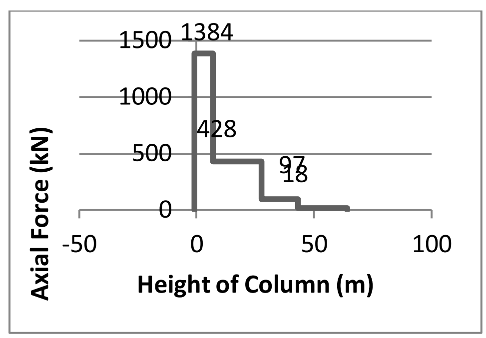

Fig14 Distribution of axial load in column S11

3 Variation of Support Reactions

The following graphs show the variation of support reactions induced due to various settlements for case – 5.

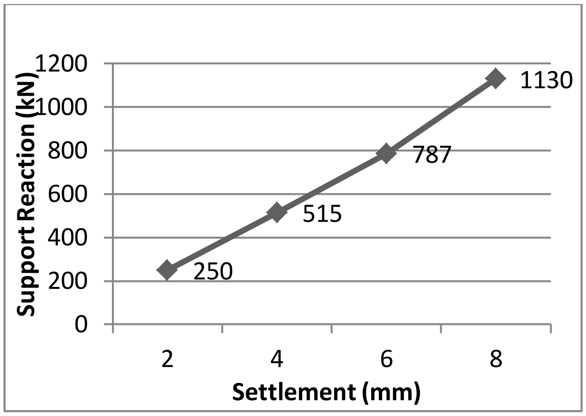

Fig 15 Variation of support reaction of column S9L

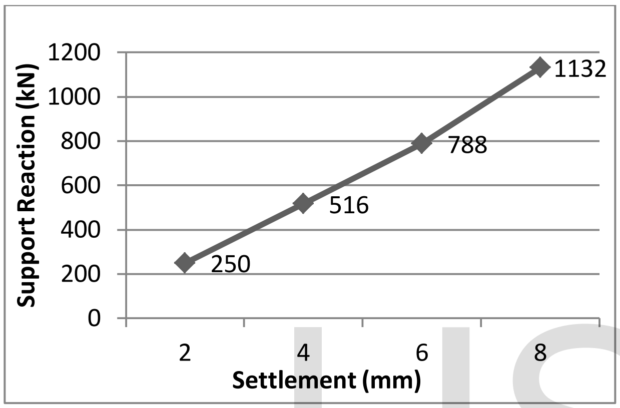

Fig 16 Variation of support reaction of column S9R

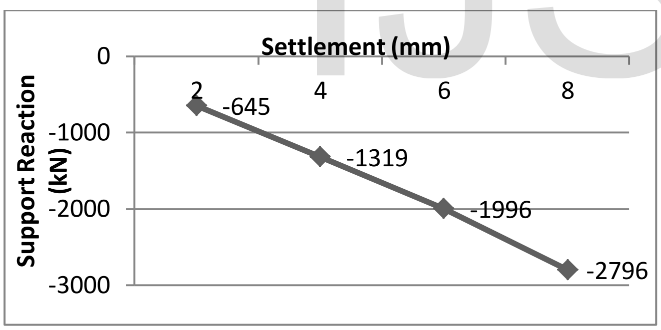

Fig 17 Variation of support reaction of column S13

4 variation of weight of steel

The following graph shows the weight of steel required for different cases.

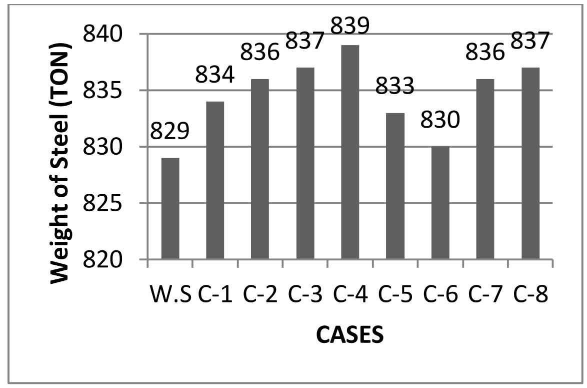

Fig 18 Weight of steel required for different cases

DISCUSSION OF RESULTS

1. Axial loads induced in the columns

These are shown in figures 9, 10, 11, 12, 13 and 14.

It can be seen that in all cases a tensile force is induced in the members of the column on which the settlement is applied. These tensile forces are greatest at the bottom of the building and decrease in magnitude up the frame. Naturally such members will normally be in compression due to the dead plus super imposed loads, and so the effect of the settlement to reduce these compressive forces throughout the columns on which the settlement is applied.

On the other hand compressive forces are induced in the members of the columns immediately on either side of the column on which the settlement is applied. These forces also have their maximum value at the bottom of the structure and decrease steadily upwards. Such forces will of course increase the compression which already exists in these members.

2 Variation of support reactions

These are shown in figures 15, 16 and 17.

It can be seen that in all cases a negative reaction (tensile force) is induced in the supports of the column on which the settlement is applied and variation of these support reactions are linear from 2mm to 8mm settlement with 2mm scale.

On the other hand positive reactions (compressive force) are induced in the supports of the columns immediately on either side of the column on which the settlement is applied and these variations are also observed to be linear from 2mm to

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8mm settlement with 2mm scale.

From the figures 1, 2, 3, 4, 5, 6, 7 and 8 it can be seen that the settlement of the end column produces greater effects over a wider area than that from any interior column. Finally it can be observed that the increase in the reactions and axial loads in the columns is not greater than 10% for members at the bottom of the structure where the effect of settlement is more severe.

3 Variation of weight of steel

These are shown in figure 18

The weight of steel was increased after applying the settlement for all cases and it can be observed that case 4 needs maximum weight of steel and increase in weight of steel will not exceed 0.25 percent.

COMMENTS AND CONCLUSIONS

The results obtained are applicable to this particular structure and also to similar structures with same bracing system. It would clearly be unwise to claim a sweeping generalization from this investigation. Nevertheless it does appear to suggest that, for such a structure:

1. The significant forces induced are confined to the bottom half of the structure, and these are decrease steadily upwards.
2. The settlement of the end column produces greater effects over a wider area than that from any interior column.

In this project, the structure has been analyzed and redesigned by considering the loads induced due to settlement of supports with magnitudes of 2mm, 4mm, 6mm and 8mm. It is observed that the results for 8mm settlement are critical. The conclusions for differential settlement of 8mm are given below:

a. The increase in the axial loads in columns is not greater than 10% for members at the bottom of the structure where the effect of settlement is more severe.
b. The increase in the weight of steel is not greater than 2.5% for a critical case.

Thus it would appear from this information that if a differential settlement of 8mm is to be tolerated in such a structure, the design engineer should increase initially; either the axial loads in the columns by 10% or the weight of the members by 2.5% for the members most affected in the bottom half of the structure.

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