Application of TLBO Algorithm for Optimizing Design Eccentricity in R.C.C buildings

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Abstract - Modern structures rarely achieve structural symmetry because of complex designs. Even in symmetric structures, the position of the structural components induces asymmetry. Such an asymmetry, even if it is small, can produce a torsional response coupled with a translational response. The horizontal torsion effect which is generated by the eccentricity between the center of mass and center of stiffness has a conspicuous impact on the total response of the building. To deal with earthquake-induced torsion in buildings, modern codes have introduced the so-called accidental design eccentricity (ADE). This paper presents an application of the Teaching Learning Based Optimization (TLBO) Algorithm for reducing accidental design eccentricity. The algorithm works by reorienting columns and calculating the Center of Stiffness for best possible combinations, and thus reducing the accidental design eccentricity developed in the structure. This optimization helps in reducing the torsional effect which results in a reduction in the overall design cost of the structure. This paper shows the effective implementation of the TLBO algorithm for solving structural engineering problems with reduced computational efforts and design time.

Key Words: Teaching–learning-based optimization; Multi-objective optimization, Design eccentricity, Torsion

1. INTRODUCTION

The TLBO algorithm is a teaching-learning process inspired algorithm and is based on the effect of the influence of a teacher on the output of learners in a class. TLBO is a population-based algorithm that simulates the teaching-learning process of the classroom. This algorithm requires only the common control parameters such as the population size and the number of generations and does not require any algorithm-specific control parameters.

The orientation of column is an important crieteria to be considered while designing an Earthquake Design on a Structure. Poor orientation of the columns will develop eccentricity. Eccentricity is developed in a Structure when COM and COS of the structure do not coincide. This generates a Torsion becauses of the forces acting at COM and COS separated by an eccentricity which acts as a lever arm. This additional Torsional effects produced on the Structures, causes greater damaging effects. The problem of development of eccentricity in Multi-stories R.C.C buildings has been a frequent case in Earthquake-prone zone.

This can be minimized by positioning the column in an orientation so as to avoid eccentricity. Once the torsion effect is minimized on the Structure it will give us an economical design as the forces acting on the Structure are also reduced.

Manually changing the eccentricity by trial and error process can be cumbersome and time-consuming. This is also one of the primary reasons for less work being carried out in this region.

The efforts can be reduced to a fraction by using the Evolutionary Algorithm for Optimization. Once such Algorithm is Teaching Learning Based Optimization Algorithm (TLBO). The working of TLBO is divided into two parts 'Teacher phase' and 'Learner phase'. Working in both these phases is explained below.

1.1 Teacher Phase

This is the first phase of the algorithm where the teacher tries to increase the mean of the class of students, here the teacher is the best solution and students are the other possible solutions.

Assume that there are 'm' number of subjects at every iteration. Subjects are design variable in this context. Let the number of learner's be 'n' and Mj,i be the mean result of the class in a particular subject 'j'. The best result among the class X_{best} which is obtained by considering all subjects together in the entire population of the learners and k_{best} be the result of the best learner. Once the best learner is identified it is considered as a Teacher by the Algorithm.

This best learner becomes the new teacher which again repeats the process until an overall best solution is obtained. All the accepted functions values at the end of the teacher phase are maintained and are used the input to the learner phase. Thus the learner phase depends on the Teachers phase.

1.2 Learner Phase

This phase of the algorithm simulates the learning of the students (i.e. learners) through interaction among themselves. The students can also gain knowledge by discussing and interacting with other students. A learner will learn new information if the other learners have more knowledge than him or her.

In the basic TLBO algorithm, the result of the learners is improved either by a single teacher (through classroom teaching) or by interacting with other learners. The interactions are random, this helps learners to learn new information if any other students have. the teaching factor in the basic TLBO algorithm is either 2 or 1, which reflects two extreme circumstances where a learner learns either everything or nothing from the teacher.

During the course of optimization, this situation results in a slower convergence rate of the optimization problem. Considering this fact, to enhance the exploration and exploitation capacities, some improvements have been introduced to the basic TLBO algorithm.

2. PROBLEM STATEMENT

TLBO Algorithm for a constrained function was modified to suit the design eccentricity problem. Following models were prepared and tested using the Algorithm. All the models are G+5 Multistorey buildings with following configurations.

Model 1: Columns dimension - 350*300 mm
Beam dimension - 230*430 mm
Length of the beam - 6000 mm

Model 2: Columns dimension - 350*300 mm
Beam dimension - 230*430 mm
Length of the beam - 4000 mm

Model 3: Columns dimension - 350*300 mm
Beam dimension - 230*430 mm
Length of the beam - 6000 mm

All the models had Concrete of grade - M-25

All the models had Steel of grade – Fe- 415

Following codes were used for refrences

1) "IS 1893 (Part 1) : 2016." Criteria for Earthquake Resistant Design of Structures. Bureau of Indian Standards.
2) "IS: 875 (Part 3) - 2015." Code of Practice for Design Loads (Other Than Earthquake) for Buildings and Structures. Bureau of Indian Standards.
3) "IS: 800-2007 ."General construction in steel-code of practice. Bureau of Indian Standards.

Table -1: Output table

Model	Eccentricity (X,Y) (TLBO)	Eccentricity (X,Y) (Manual)
1	1.5, 2.6	1.49, 2.6
2	4.46, 2.1	4.46, 2.1
3	2, 3	2, 3

Outputs are presented in Table-1, it shows the final eccentricity obtained using both Manual and Algorithmic method.

The manual solutions were obtained by first calculating the COM by considering the mass of beams, columns, slabs. Next COS was calculated by considering all the stiffness in the building to be contributed by columns only and the stiffness contribution by slab and beam to be negligible. Difference of both COM and COS gives design eccentricity produced in the building.

In the Algorithmic method solution consisted of all possible orientation of columns. Each of these is then used to calculate COM, COS and the design eccentricity in the building.

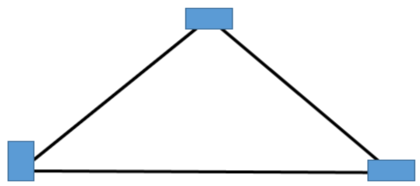

Figure 1: Model 1

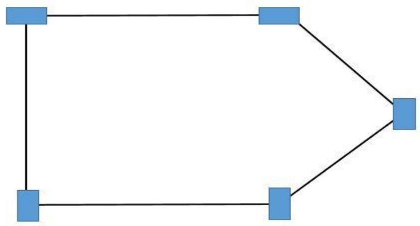

Figure 2: Model 2

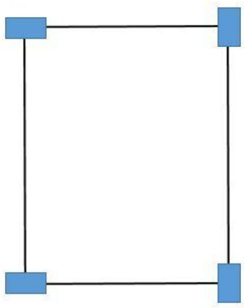

Figure 3: Model 3

3. CONCLUSIONS

It can be observed from the review of applications of the TLBO algorithm that the algorithm can be modified to suit the Structural engineering problems.

A comparatively less number of models have been selected as the sole purpose was to have better performance for TLBO algorithm.

TLBO Algorithm requiring less specific control parameters proved to be highly effective in modifying to suit the design eccentricity problem. It reduced the effort in tuning the algorithm for controlling the parameters. The results obtained are similar to the one obtained using manual calculations except for the effort and time. The run time has been reduced to fractions of seconds for all the models considered.

TLBO is simple yet powerful with much-improved performance.

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