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CONSTRUCTION SEQUENCE ANALYSIS AND CONVENTIONAL LUMPED ANALYSIS CONSIDERING P-DELTA EFFECT BY USING ETABS

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Abstract: While analyzing a multistorey building frame, conventionally all the probable loads are applied after modeling the entire building frame. But in practice the frame is constructed in various stages. Accordingly, the stability of frame varies at every construction stage. Even during construction freshly placed concrete floor is supported by previously cast floor by formwork. Thus, the loads assumed in conventional analysis will vary in transient situation. Obviously, results obtained by the traditional analysis will be unsuitable. Therefore, the frame should be analyzed at every construction stage taking into account variation in loads. The phenomenon known as Construction Sequence Analysis considers these uncertainties precisely. Therefore, the building structure should be analysed at every stage of construction taking into account the load variations. In this project two cases have been considered. In Case 1 the multistoried building (G+21 storied) with floating columns and transfer girder will be analysed by response spectrum method and considering P-delta effect as a whole for the subjected loading and in Case 2 the multistoried building (G+21storied) with floating columns and transfer girder will be analysed by response spectrum method with reference to the construction sequence or staged construction and considering P-delta effect. In the present study a G+21 storey multistoried R.C.C building model is modelled using Etabs 2018 software. Response spectrum analysis is made by considering building situated in zone III.Building models are analyzed by Etabs 2018 software to study the effect of maximum positive moment, maximum negative moment, maximum shear forces, maximum deflection, maximum torsion moment of transfer girder beam and total axial load under transfer girder and floating column etc

Keywords: Construction Sequence Analysis, P-delta effect, Floating columns and transfer girder Response spectrum analysis, Etabs software.

I. Introduction

A. Structural Concept

The structural analysis of multistorey buildings is one of the areas that have attracted a great deal of Engineering research efforts and designers' attention. There is one area, however, which has been ignored by many previous investigators, i.e., the effects of construction sequence in a multistorey frame analysis. In the structural analysis of multistorey buildings, there are three important facts that have very significant effects on the accuracy of the analysis but are seldom considered in the practice. They are:

1. The effect of sequential application of loads due to the sequential nature of construction;
2. The consideration of variation in loads during construction; and
3. The differential column shortening due to the different tributary areas that the exterior and interior columns support.

The effect of the sequential application of loads due to the sequential nature of construction is an important factor to be considered in the multistorey frame analysis (Fig.1). In fact, the structural members are added in stages as the construction of the building proceeds and hence their dead load is carried by that part of the structure completed at the stage of their installation. Therefore, it is clear that the distribution of displacements and stresses in the part of the structure completed at any stage due to the dead load of members installed by that stage does not depend on sizes, properties, or the presence of members composing the rest of the structure. The correct distribution of the displacements and stresses of any member can be obtained by accumulating the results of analysis of each stage. Ignoring this effect may lead to the seriously incorrect results of analysis, particularly at the upper floors of the building. Therefore, it is necessary to calculate the load distribution and analyze the structure at every construction stage and to make sure that the loads carried by the supporting components do not exceed their strength. However, it is rather difficult to estimate accurately the load distribution in the system because of the time dependent behaviour of building materials and the complexity of construction stages.

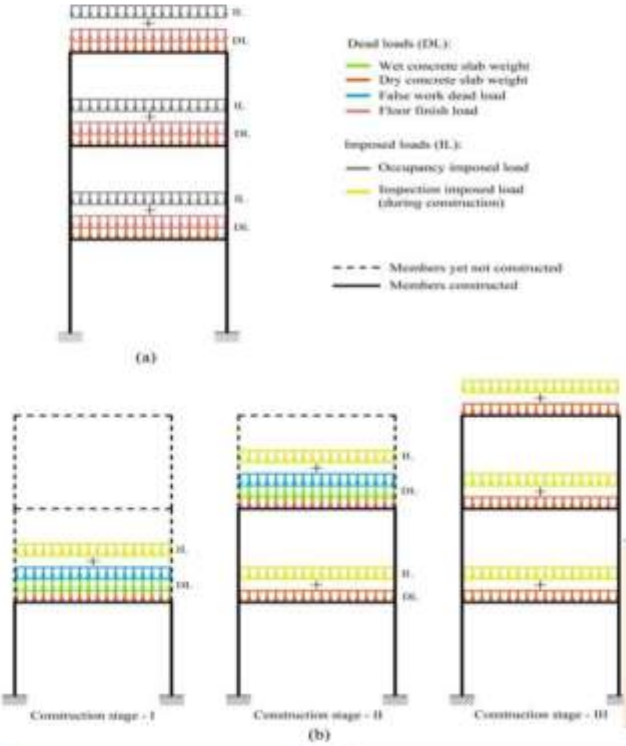

Fig. 1 Frame Analysis: (a) Conventional Analysis; (b) Construction Stage Analysis

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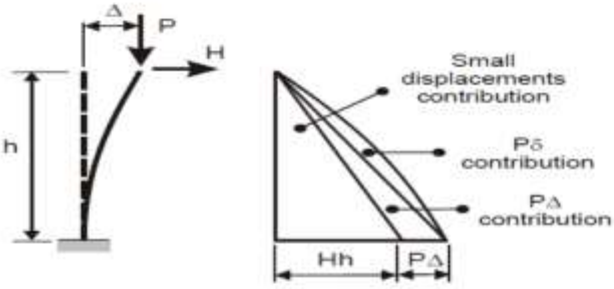
B. Objectives of the Present Study

1. The main objective of this work is to reduce the potential for structural failure during the construction phase ultimately reducing the risk of injury and delays in construction projects.
2. To understand the high-rise structure behavior analytically during construction at different stages using construction sequence analysis.
3. Detailed analytical study on Construction Sequence Analysis with the conventional method of high-rise buildings using Etabs 2018 software.
4. In this project two cases have been considered. In Case 1 the multistoried building (G+21 storied) with floating columns and transfer girder will be analysed by response spectrum method and considering P-delta effect as a whole for the subjected loading and in Case 2 the multistoried building (G+21storied) with floating columns and transfer girder will be analysed by response spectrum method with reference to the construction sequence or staged construction and considering P-delta effect.
5. Comparative study of Construction Sequence analysis with the conventional method.
6. Building models are analyzed by Etabs 2018 software to compare the response of buildings in terms of maximum positive moment, maximum negative moment, maximum shear forces, maximum deflection, maximum torsion moment of transfer girder beam and total axial load under transfer girder and floating column etc.

C. P-Δ Effect

The P-Delta effect is the second order effect on shears and moments of frame members due to the action of the vertical loads, interacting with the lateral displacement of buildings, resulting from the seismic forces. The structures behave flexible against applied seismic lateral loads as the columns are subjected to compressive loads. Where

"P" = The gravity load
"Δ" =The displacement experienced through first order or elastic analysis for lateral forces
"h" = Height of column
"H" =Horizontal lateral forces
"P-δ" only becomes significant at larger displacement values



a b

Fig. 2 P- about Column: (a) Column; (b) Bending Moment.

P Big Delta Effect (P-): P- is referred to effects of gravity loads applied on structures which are laterally displaced. For reference, seismic or wind loads create horizontal displacements (Δ) and vertical loads (P) also known as gravity loads also act vertically on displaced structure at the same time. So secondary moments developed on the structure is equal to gravity load (P) multiplied by horizontal displacement (Δ).

P- Small Delta Effect (P- δ): P- δ is referred to the axial load effects in a member subjected to deflection between the end points. For instance, loads on columns due to wind load, earthquake forces and self-weight results in deflection as the result of beams which are supported on it. The bending moments developed is proportional to the axial load. i.e., P multiplied by the curvature it produced during bending i.e., δ. It has to be considered that even beams which are loaded axially will also experience these kinds of effects.

II. MATERIALS AND METHODS

A. Preliminary data required for Conventional Lumped Analysis and Construction Sequence Analysis of Rectangular geometry Considering P-Delta for zone III

Two models are prepared in this study for the analysis and study. The constant parameters in all the two models are as below:

Model No 1: Conventional Lumped Analysis of Rectangular geometry Considering P-Delta for zone III.

Model No 2: Construction Sequence Analysis of Rectangular geometry Considering P-Delta for zone III.

Table 1 Parameters to be consider for Construction Sequence Analysis and Conventional Lumped Analysis Considering P-Delta Effect by using Etabs for zone III

Sr. No.	Parameter	Values
1.	Number of storey	G+21
2.	Floor height	3.2m
3.	Infill wall	150 mm thick
4.	Materials	Concrete 40 and Reinforcement Fe 500
5.	Frame size	18m X 24m building size
6.	Grid spacing	4.5m grids in X-direction and 6m grids in Y-direction.
7.	Size of column	600 mm x 600 mm,750mmx750mm
8.	Size of beam	300mm x 600 mm
9.	Transfer girder at first level	600 mm x 1400 mm
10.	Floating column	600mm x 600 mm
11.	Depth of slab	225 mm
12.	Plan area	432^{2}
13.	Support condition	Fixed
14.	Total height	68.7m

A. **Load details**

Table 2 Load details for Construction Sequence Analysis and Conventional Lumped Analysis

a.	Dead load for Conventional Lumped Analysis	In ETABS the software itself calculates the dead loads by applying a self-weight multiplier factor of one which is taken by the structure and the rest load cases are kept zero. Its defined in the load cases section.
b.	Dead load for Construction Sequence Analysis	In etabs software dead load replaced by Sequential dead load. In ETABS the software itself calculates the dead loads by applying a self-weight multiplier factor of one which is taken by the structure and the rest load cases are kept

		zero. Its defined in the load cases section.
c.	Live load on roof and floors	2 kN/m^2 (roof) and 4 kN/m^2 (Floors) as per IS:875 (part -2)
d.	Floor finish on roof and floors	1.5 kN/m^2 as per IS:875 (part -2)
e.	Wall load on all levels	7.8 kN/m
f	Wall load on 21st floor	4.5 kN/m

B. Seismic data required for Construction Sequence Analysis and Conventional Lumped Analysis

Table 3 Seismic data required for Construction Sequence Analysis and Conventional Lumped Analysis

Sr. No.	Parameter	Values as per IS 1893:2016 (Part1)	Reference
1.	Type of structure	Special RC moment resisting frame	Table 9, Clause 7.2.6
2.	Seismic zone	III	Table 3, Clause 6.4.2
3.	Location	Pune	Annex E
4.	Zone factor (Z)	0.16	Table 2, Clause
5.	Type of soil	Medium Soil	Clause 6.4.2.1
6.	Damping	5 %	Clause 7.2.4
7.	Response spectra	As per IS 1893 (part 1):2016	Figure 2, Clause 6.4.6
8.	Load combinations	Conventional Lumped Analysis 1) 1.5(DL + IL) 2) 1.2(DL+IL+ EL) 3) 1.5(DL + EL) 4) 0.9DL + 1.5 EL Construction Sequence Analysis 1) 1.5(DLS + IL) 2) 1.2(DLS+IL+ EL) 3) 1.5(DLS + EL) 4) 0.9DLS + 1.5 EL	Clause 6.3.1
9.	Response reduction factor (R)	4	Table 9, Clause 7.2.6
10.	Importance factor (I)	1.2	Table 8, Clause 7.2.3

Wind data required for analysis

Table 4 Wind data required for Construction Sequence Analysis and Conventional Lumped Analysis

Sr. No.	Parameter	Values as per IS 875-2015 (Part3)	Reference
1.	Basic wind speed (V_b)	Pune=39m/sec,	Annex A
2.	Risk coefficient k_1	1	Table 1, Clause 6.3.1
3.	Terrain category	3	Table 2, Clause 6.3.2.2
3.	Topography Factor k_3	1	Table 3, Clause 6.4.2
3.	Importance Factor k_4	1	Clause 6.3.4
5.	Windward coefficient cp	0.8	Clause 7.3.3
6.	Leeward coefficient cp	0.5	Clause 7.3.3

D. Model No 1 and 2: Plan of rectangular geometry for Conventional Lumped Analysis and Construction Sequence Analysis Considering P-Delta for zone III

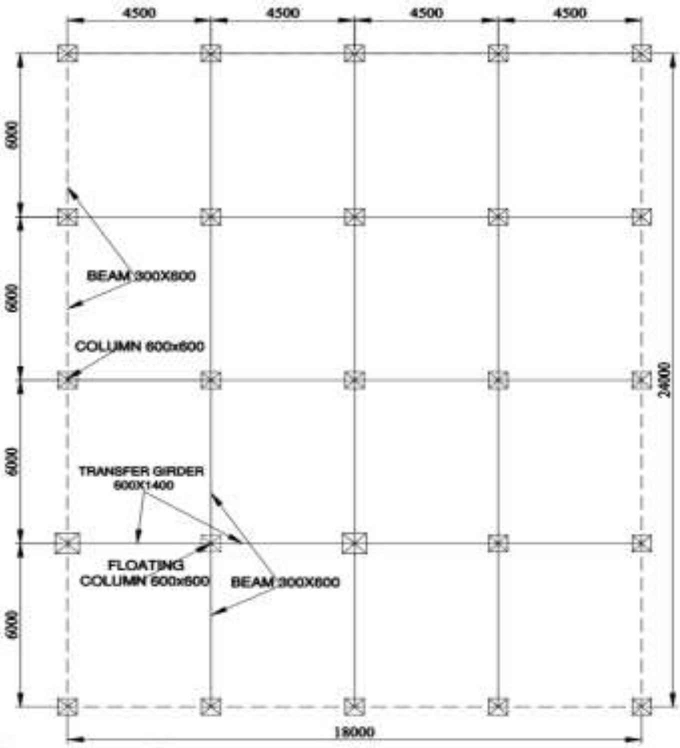


Fig. 3 First floor Plan of rectangular geometry for Conventional Lumped Analysis and Construction Sequence Analysis Considering P-Delta for zone II

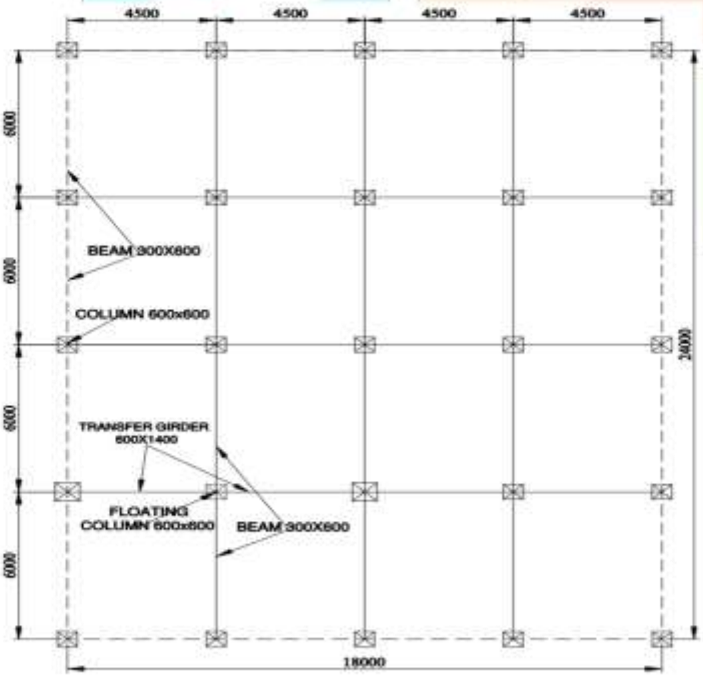


Fig. 4 2^{nd} to 21^{st} floor Plan of rectangular geometry for Conventional Lumped Analysis and Construction Sequence Analysis Considering P-Delta for zone II

E. Model No 1 and 2: Elevation of Rectangular geometry of Conventional Lumped Analysis and Construction Sequence Analysis of Considering P-Delta for zone III

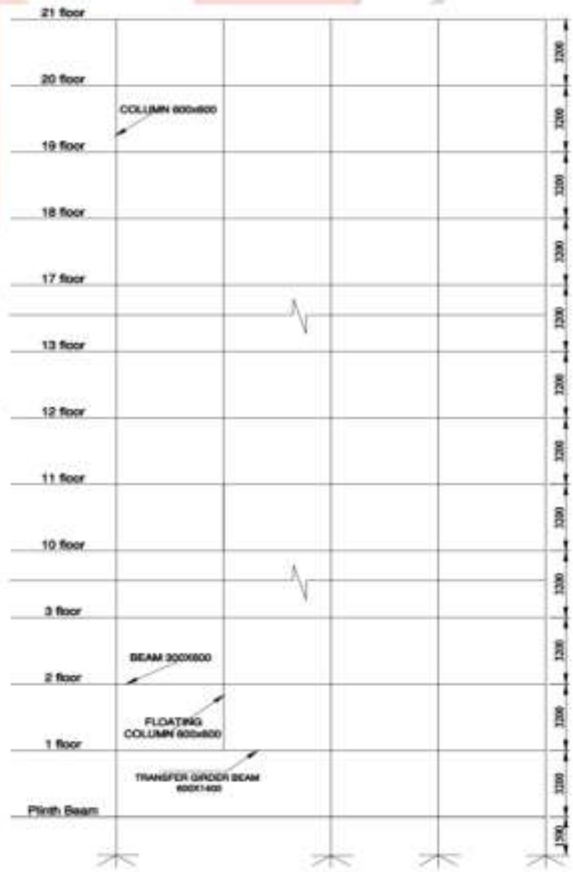


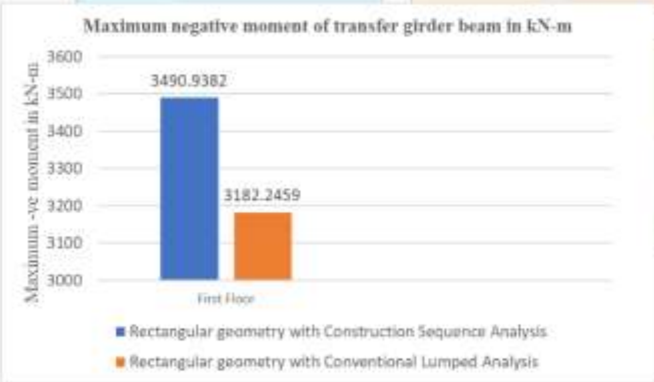
Fig. 5 Elevation of Rectangular geometry of Conventional Lumped Analysis and Construction Sequence Analysis of Considering P-Delta for zone III

III. RESULTS AND DISCUSSION

3.1 Maximum positive moment of transfer girder beam (in kN- m) for 1.5(DLS+LL) and 1.5(DL+LL) Case:
Maximum positive moment of transfer girder beam values for rectangular geometry Construction Sequence Analysis and Conventional Lumped Analysis Considering P-Delta Effect for zone III.

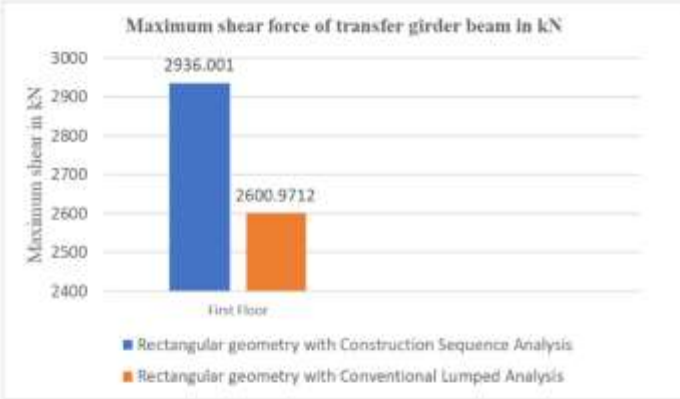
Graph 1 Maximum positive moment of transfer girder beam in kN-m

3.2 Maximum negative moment of transfer girder beam (in kN- m) for 1.5(DLS+WLX) 1.5(DL+WLX) Case:
Maximum negative moment of transfer girder beam values for rectangular geometry Construction Sequence Analysis and Conventional Lumped Analysis Considering P-Delta Effect for zone III



Graph 2 Maximum negative moment of transfer girder beam in kN-m

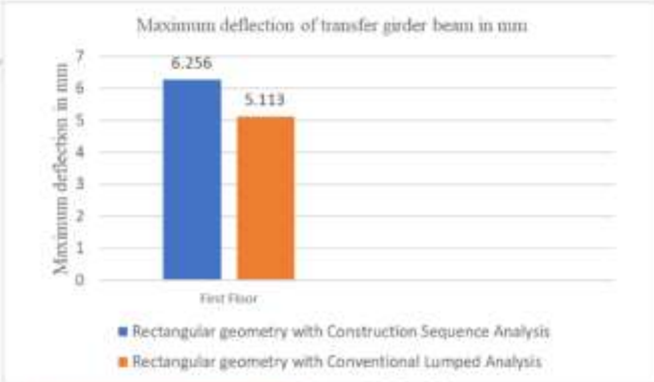
3.3 Maximum shear force of transfer girder beam (in kN) for 1.5(DLS+LL) ,1.5(DL+LL) Case:
Maximum shear force of transfer girder beam values for rectangular geometry Construction Sequence Analysis and Conventional Lumped Analysis Considering P-Delta Effect for zone III



Graph 3 Maximum shear force of transfer girder beam in KN

3.4 Maximum deflection of transfer girder beam (in mm) for DLS, DL Case:

Maximum deflection of transfer girder beam values for rectangular geometry Construction Sequence Analysis and Conventional Lumped Analysis Considering P-Delta Effect for zone III



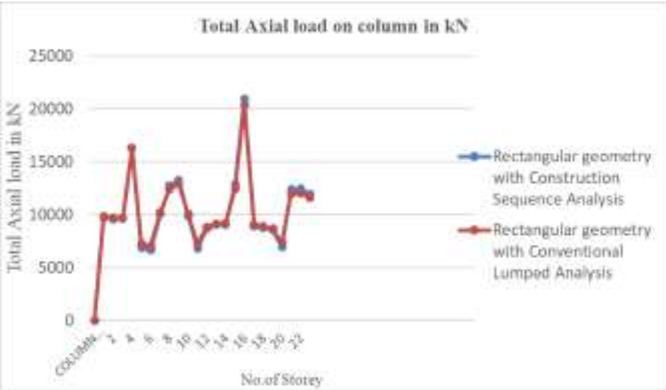
Graph 4 Maximum deflection of transfer girder beam in mm

3.5 Maximum torsion moment of transfer girder beam (in kN-m) for (1.5DLS+1.5SPEC2+0.45SPEC3), (0.9DL+1.5SPEC2+0.45SPEC3)
Maximum torsion moment of transfer girder beam values for rectangular geometry Construction Sequence Analysis and Conventional Lumped Analysis Considering P-Delta Effect for zone III

Graph 5 Maximum torsion moment of transfer girder beam in kN-m

3.6 Total Axial load on column (in kN) for 1.5(DLS+LL), 1.5(DL+LL)

Total Axial load on column values for rectangular geometry Construction Sequence Analysis and Conventional Lumped Analysis Considering P-Delta Effect for zone III.



Graph 6 Total Axial load on column in kN

IV. CONCLUSIONS

Based on the broad investigations and comparisons following conclusions were drawn

1. The outcome obtained from analysis shows the moment is taken by transfer girder beam with Construction Sequence Analysis is more when compare to transfer girder beam with Conventional Lumped Analysis. Hence it is necessary that for multistory building frame with transfer girders and floating columns system, the construction sequence effect shall be taken into consideration into account.
2. Construction sequence analysis in structures of RCC is necessary to improve the analysis accuracy in terms of displacement, axial, moment and shear force in supporting beam and column near of it and also for the whole the structure overall.
3. Regarding displacement results, structure considered sequential effects shows the worst part than that of structure.
4. Inclusion of sequential load case in the analysis of multistoried RCC structure provides more realistic design than the conventional design.
5. Maximum positive moment of transfer girder beam values for rectangular geometry construction sequence analysis is 13.39 % more than maximum positive moment of transfer girder beam values for rectangular geometry conventional lumped analysis.
6. Maximum negative moment of transfer girder beam values for rectangular geometry construction sequence analysis is 8.84 % more than maximum negative moment of transfer girder beam values for rectangular geometry conventional lumped analysis.
7. Maximum shear force of transfer girder beam values for rectangular geometry construction sequence analysis is 11.41 % more than Maximum shear force of transfer girder beam values for rectangular geometry conventional lumped analysis.
8. Maximum deflection of transfer girder beam values for rectangular geometry construction sequence analysis is 18.27 % more than Maximum deflection of transfer girder beam values for rectangular geometry conventional lumped analysis.
9. Maximum torsion moment of transfer girder beam values for rectangular geometry construction sequence analysis is 5.84 % more than Maximum torsion moment of transfer girder beam values for rectangular geometry conventional lumped analysis.

V. ACKNOWLEDGMENT

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