Comparative Study of Flat Slab with Old Traditional Two Way Slab

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Abstract- A traditional common practice in construction is to support slab by beam and beam supported by column this may be called as beam slab load transfer construction technique. As due to this old traditional construction net height of room is reduced. Hence to improve aesthetical and structural aspect of multi storey, shopping mall ,offices, warehouses , public community hall etc. are constructed in such a way were slab are directly on columns. This types of slab directly supported on column termed as flat slab.

The present objective of this work is to compare behavior of flat slab with old traditional two way slab. The parametric studies comprise of maximum lateral displacement, storey drift and axial forces generated in the column. For these case studies we have created models for two-way slabs and flat slab without shear wall for each plan size of 16X24 m and 15X25 m, analyzed with Staad Pro. 2006 for seismic zones III, IV and V with varying height 21m, 27 m , 33 m and 39 m. This investigation also told us about seismic behavior of heavy slab without end restrained.

Keywords— Axial Forces, Flat Slab, Seismic Zones, Shear Wall, Two-way slab, Storey Drift.

I. INTRODUCTION

IJIET In general normal frame construction utilizes columns, slabs and Beams. However it may be possible to undertake construction without providing beams, in such a case the frame system would consist of slab and column without beams. These types of slabs are called flat slabs. The slab directly rests on the column and load from the slab is directly transferred to the columns and then to the foundation.

Flat slabs have been widely used in building construction due to their advantages in reducing storey height and construction period (compared with RC frames with beams and columns), leading to a reduction of construction costs. Two- way slab, the slab is supported by beams, the load of both slab and beams is conveyed to columns and footings. Flat slabs are extensively used to resist wind and seismic forces in low-to-moderate seismicity regions such as the Mediterranean area as compare to two way slab.

The behavior of this type of structural system under gravitational loads is well established. The flat slab is often thickened closed to supporting columns to provide adequate strength in shear and to reduce the amount perimeter of the critical section, for shear and hence, increasing the capacity of the slab for resisting two-way shear and to reduce negative bending moment at the support.

Flat slab Building structures are significantly more flexible than traditional concrete slab under seismic excitations. The slab that satisfies architectural demand for better illumination, requires simple formwork that can be removed faster (than other slabs) and guarantees open vision while making optimum use of the available space leads to an admired concept in field of structural engineering i.e. reinforced concrete flat slab. U.Gupta et.al [7] studies about flat slab building structures which are more significantly flexible than traditional concrete frame/wall or frame structures, thus becoming more vulnerable to seismic loading. R.K.Makode et.al[10] discussed about the flat slab buildings in which slab is directly rested on columns, have been adopted in many buildings constructed recently due to the advantage of reduced floor to floor heights to meet the economical and architectural demands.

II. PAST RESEARCH WORK

S.D.Bothara et.al [1] studies about comparative effect of earthquake on flat slab & Grid floor system consisting of beam spaced at regular intervals in perpendicular directions, monolithic with slab.

A.B.Climent [2] investigates about the effective width of reinforced concrete flat slab structures subjected to seismic loading on the basis of dynamic shaking table tests. The study is focused on the behavior of corner slab column connections with structural steel I- or channel-shaped sections (shear heads) as shear punching reinforcement. To this end, a 1/2 scale test model consisting of a flat slab supported on four box-type steel columns was subjected to several seismic simulations of increasing intensity. It is found from the test results that the effective width tends to increase with the intensity of the seismic simulation, and this increase is limited by the degradation of adherence between reinforcing steel and concrete induced by the strain reversals caused by the earthquake. Also, significant differences are found between the effective width obtained from the tests and the values predicted by formula proposed in the literature. These differences are attributed to the stiffening effect provided by the steel profiles that constitute the punching shear reinforcement.

M.A. Eebrik [3]{a}) discussed about Flat-slab RC buildings exhibit several advantages over conventional moment-resisting frames. However the structural effectiveness of flat-slab construction is hindered by its alleged inferior performance under earthquake loading. This is a possible reason for the observation that no fragility analysis has been undertaken for this widely-used structural system. This study focuses on the derivation of fragility curves using medium-rise flat-slab buildings with masonry infill walls. The developed curves were compared with those in the literature, derived for moment-resisting RC frames. This study also concluded that earthquake losses for flat-slab structures are in the same range as for moment-resisting frames for low limit states, and considerably different at high damage levels.

M.A. Eebrik [4]{b}) focuses on the study of earthquake records compatible with the design spectrum selected to represent the variability in ground motion. Inelastic response-history analysis was used to analyze the random sample of structures subjected to the suite of records scaled in terms of displacement spectral ordinates, whilst monitoring four performance limit states. The fragility curves developed from this study were compared with the fragility curves derived for moment-resisting RC frames. The study concluded that earthquake losses for flat-slab structures are in the same range as for moment-resisting frames.

M.A. Eebrik [5] discussed about loss estimation analysis of flat-slab structures, a reinforced concrete structural form that exhibits behavior and response patterns distinct from conventional moment frames. The fragility information obtained for flat-slab structures presented in a companion paper is implemented into software HAZUS. The latter program includes many existing structural types, but does not deal with flat-slab structures. Fragilities already available in software HAZUS. After implementation, the earthquake losses in flat-slab buildings are predicted in comparison with the existing structural types in software HAZUS by using different scenario earthquakes for a selected study region. The prediction results are consistent with the seismic response characteristics of the compared structural types.

E. S. Finzel et al[6] The timing of initiation of flat-slab subduction beneath southern Alaska and the upper plate record of this process are not well understood. We explore the record of flat-slab subduction in southern Alaska by integrating stratigraphic, provenance, geochronologic, and thermochronologic data from the region directly above and around the perimeter of ongoing flat-slab subduction.

U.Gupta et.al [7] studies about flat slab building structures which are more significantly flexible than traditional concrete frame/wall or frame structures, thus becoming more vulnerable to seismic loading. Therefore, the characteristics of the seismic behavior of flat slab buildings suggest that additional measures for guiding the conception and design of these structures in seismic regions are needed. To improve the performance of building having flat slabs under seismic loading, provision of part shear walls is proposed in the present work. The object of the this work is to compare the behavior of multi-storey buildings having flat slabs with drops to the two way slabs with beams and to study the effect of part shear walls on the performance of these two types of buildings under seismic forces. This work provides a good source of information on the parameters lateral displacement and storey drift.

S.W.Han et.al [8] told about the effective beam width model (EBWM) used for predicting lateral drifts and slab moments under lateral loads. They also studies on slab stiffness with respect to crack formation. This studies developed equations for calculating slab stiffness reduction factor by conducting nonlinear regression analysis using stiffness reduction factors.

E. Humphreys[9] studies about flat subduction of the Farallon plate beneath western USA during the Laramide orogeny was caused by the combined effects of oceanic plateau subduction and unusually great suction in the mantle wedge, the latter being a result of rapid slab sinking during the Sevier-Laramide orogeny. Once in contact with basal North America, the slab cooled and hydrated the lithosphere. Upon removal, asthenospheric contact with lithosphere resulted magmatic production that was especially intense where the basal lithosphere was fertile (in what now is the Basin and Range), and the heated lithosphre was weakened. This made the base of western USA lithosphere convectively unstable and small-scale convection has affected many areas. With slab sinking and the unloading of the continent, the North America elevated into a broad plateau, and the weak portion gravitationally collapsed. With development of a transform plate boundary the western part of the weak zone is partly entrained with the Pacific plate and deformation is dominated by shear.

R.K.Makode et.al [10] discussed about the flat slab buildings in which slab is directly rested on columns, have been adopted in many buildings constructed recently due to the advantage of reduced floor to floor heights to meet the economical and architectural demands.

V. C. MANEA et.al [11] study on recent seismic and magnetotelluric experiments, aimed at better characterizing the shape and state of the sub ducting slab and continental crust beneath Central Mexico, exposed significant differences with conclusions of previous studies. New slab geometry is revealed in which the sub ducting Cocas slab is perfectly flat.

Y. Mirzaei et.al [12] studies about the column failure due to an explosion can propagate in the structure through punching shear failure at the location of the neighboring columns, leading to progressive collapse. An analytical model is developed to be used in a finite element model of flat plate/slab structures to estimate the initiation of punching shear failure as well as post-punching shear response using ABAQUS.

K. S. Patil et.al [13] study about optimum design of reinforced concrete flat slab with drop panel according to the Indian code (IS 456-2000) is presented. The objective function is the total cost of the structure including the cost of slab and columns. The cost of each structural element covers that of material and labour for reinforcement, concrete and formwork. The structure is model and analyzed using the direct design method. The optimization process is done for different grade of concrete and steel. The comparative results for different grade of concrete and steel is presented in tabulated form. Optimization for reinforced concrete flat slab buildings is illustrated and the results of the optimum and conventional design procedures are compared. The model is analyzed and design by using MATLAB software. Optimization is formulated is in nonlinear programming problem (NLPP) by using sequential unconstrained minimization technique (SUMT).

K. S. Patil et al [14] Sequential unconstrained minimization technique (SUMT) is used for the solution of a comprehensive minimum cost design problem formulation. The formulation, based on Indian codes of practice (IS 456-2000), Solutions to the nonlinear programming problem are obtained with an appropriate computer program, This is used for solving a wide range of typical flat slab designs with varying span-to-depth ratios, live and dead loads, different grades of concrete and steel. A related sensitivity study enables the comparison of optimal and standard solutions. The different conditions of flat slabs are analyzed and design by using MATLAB software.
V.K. Rahman1 et.al [15] work on design of R.C.C. as well as pre-stressed concrete flat slabs for various spans and then compare the results. Programming in MS EXCEL is done to design both types of flat slabs. The idea is to reach a definite conclusion regarding the superiority of the two techniques over one another. Results reveal that a R.C.C. flat slab is cheaper than pre-stressed concrete flat slab for smaller spans but vice versa is true for larger spans.

S.RAO et.al [16]This paper presents the punching shear strength of high performance concrete (HPC) two way slabs under simply supported edge condition. Three number of HPC slabs and three numbers of normal concrete slabs as control specimens were cast and tested. All the slabs were tested under a central patch load, the results showed that the HPC slabs posses higher energy absorption, better performance, higher punching shear strengths than the control specimens.

Ramos, et.al [17] studies about the punching failure mechanism results from the superposition of shear and flexural stresses near the column, and is associated with the formation of a pyramidal plug of concrete which punches through the slab. It is a local and brittle failure mechanism. The present work reports the experimental analysis of reduced scale pre-stressed flat slab models under punching.

K.S.Sable et.al [18] focuses on tall commercial buildings are primarily a response to the demand by business activities to be as close to each other, and to the city centre as possible, thereby putting intense pressure on the available land space. Structures with a large degree of indeterminacy is superior to one with less indeterminacy, because of more members are monolithically connected to each other and if yielding takes place in any one of them, then a redistribution of forces takes place. Therefore it is necessary to analyze seismic behavior of building for different heights to see what changes are going to occur if the height of conventional building and flat slab building changes.

T.Srikanth et.al [19] studies their response under seismic conditions and to evaluate seismic retrofit schemes. Two-dimensional nonlinear push-over analysis is carried out on a typical flat slab building. The building considered is designed only for gravity loads and wind loads. Comparison with similar conventional beam-column frames shows that the flat slab buildings have low lateral stiffness, low drift capacity and have hardly any ductility, while the over strength is of similar order.

A.A.Sathawane et al [20] the aim of the project is to determine the most economical slab between flat slab with drop, Flat slab without drop and grid slab. The proposed construction site is Nexus point apposite to Vidhan Bhavan and beside NMC office, Nagpur. The total length of slab is 31.38 m and width is 27.22 m. total area of slab is 854.16 sqm. It is designed by using M35 Grade concrete and Fe415 steel. Analysis of the flat slab and grid slab has been done both manually by IS 456-2000 and by using software also. Flat slab and Grid slab has been analyzed by STAAD PRO. Rates have been taken according to N.M.C. C.S.R It is observed that the FLAT slab with drop is more economical than Flat slab without drop and Grid slabs.

V.K.Tilva et.al [21] studies about to avail a cost comparison between flat slab panel with drop and without drop in four storey lateral load resisting building for analyzing punching effect due to lateral loads. On the basis of permissible punching shear criteria according to IS 456, economical thickness of flat slab with drop and without drop are selected and cost comparison is done by using S.O.R.

N.V.Ramana et al [22] perform experimental study about High Performance (HPC) Concrete in punching shear. Two way slabs are cast and tested to know the behavior of HPC slabs in punching shear. In addition to this control slab specimens (RCC) are prepared with conventional concrete and compared the strength results with HPC slabs. In this paper experimental work procedure and analysis presented in detail. The experimental result shows that, the HPC slab specimens exhibit good strength results than the RCC slab specimens.

M. Varma et.al [23] presented paper on a method designated as Equivalent Load Method, in which equivalent load is calculated using Grashoff-Rankine formulae, and is considered to be acting on the slab. The deflection calculated using equivalent load method is found to be closer to experimental values. The negative deflection has been tackled in literature by applying a factor of 0.7 to cracking moment (Mr). The deflection thus calculated again differs considerably with the experimental values. In the paper, with the method, a procedure has been proposed in which instead of the factor 0.7 being applied to Mcr; cracking moment of inertia is proposed to be used in place of effective moment of inertia. The deflection thus calculated has been found to be comparable with experimental results. Experimental data obtained and data available in literature have been used to validate the procedure. Experimental work has been carried out for two end conditions i.e. fixed supported and simply supported two-way RC slab. Six separate specimens were casted for both end condition of different thickness, sizes and for different loads.

Widianto et.al [24] perform experimental research on 2/3-scale slab-column connections was conducted to quantify the effects of earthquake-damage and low reinforcement ratios on the punching shear strength, and to study the efficiency of various rehabilitation techniques

III. Problem Formulation

The purpose of the present work is to study the behavior of multistory building having flat slab and comparison between old traditional two way slab under seismic forces. For this purpose 54 cases of multistory buildings are considered. To study the behavior the response parameters selected are lateral displacement, column shear and base shear. All the cases are assumed to be located in zone III, zone IV and zone V.

Summary of the variables

Parameter	Variables
Zones Position of Shear Walls Plot size/Building Height/No. of Storeys	III, IV and V No Shear Wall 16m x 24m/21m/7, 16m x 24m/27m/9, 16m x 24m/33m/11, 16m x 24m/39m/13, 15m x 25m/21m/7, 15m x 25m /27m/9 15m x 25m /33m/11, 15m x 25m /39m/13

Details of case-I:

In case-I plot area of 16m x 24m and 15m x 25m is taken. The building is of (G + 6) configuration, having storey height of 3m. The columns are provided in 4m x 4m and 5m x 5m grid form respectively. The soft storey is provided at ground floor.
The sizes of beams are taken as 200mm x 400mm throughout the height of building.
The cross sectional size of strut against infill wall taken is 250mm x 600mm.
The thickness of slab is taken as 120mm.
The thickness of flat slab is taken as 150 mm throughout the slab without drop.
The sizes of columns are provided same in buildings

Sizes of columns

Storeys	Size of Column (in mm)
Two storeys from G.L. Next further storeys	350 x 350 300 x 300

Details of case-II:

In case-I plot area of 16m x 24m and 15m x 25m is taken. The building is of (G + 8) configuration, having storey height of 3m. The columns are provided in 4m x 4m and 5m x5m grid form respectively. The soft storey is provided at ground floor.
The sizes of beams are taken as 200mm x 400mm throughout the height of building.
The cross sectional size of strut against infill wall taken is 250mm x 600mm.
The thickness of slab is taken as 120mm.
The thickness of flat slab is taken as 150mm without drop.
The sizes of columns are provided same in buildings.

Sizes of columns

Storeys	Size of Column (in mm)
Two storeys from G.L. Next 4 storeys Top 3 storeys	400 x 400 350 x 350 300 x 300

Details of case-III:

In case-I plot area of 16m x 24m and 15m x 25m is taken. The building is of (G + 10) configuration, having storey height of 3m. The columns are provided in 4m x 4m and 5m x5m grid form respectively. The soft storey is provided at ground floor.
The sizes of beams are taken as 200mm x 400mm throughout the height of building.
The cross sectional size of strut against infill wall taken is 250mm x 600mm.
The thickness of slab is taken as 120mm.
The thickness of flat slab is taken as 150mm without drop.
The sizes of columns are provided same in buildings.

Sizes of columns

Storeys	Size of Column (in mm)
Three storeys from G.L.	500 x 500
Next 4 storeys	450 x 450
Top 4 storeys	400 x 400

Details of case-IV:

In case-I plot area of 16m x 24m and 15m x 25m is taken. The building is of (G + 12) configuration, having storey height of 3m. The columns are provided in 4m x 4m and 5m x5m grid form respectively. The soft storey is provided at ground floor.
The sizes of beams are taken as 200mm x 400mm throughout the height of building.
The cross sectional size of strut against infill wall taken is 250mm x 600mm.
The thickness of slab is taken as 120mm.
The thickness of flat slab is taken as 150mm without drop.
The sizes of columns are provided same in buildings.

Sizes of columns

Storeys	Size of Column (in mm)
Four storeys from G.L.	600 x 600
Next 4 storeys	500 x 500
Top 5 storeys	400 x 400

Parameters and different aspects of study:

Storey Sway and Inter-storey Drift:

Controlling storey sway or inter-storey drift of a building is an important aspect because

1. It prevents pounding of adjacent buildings in urban areas.
2. It controls plastic deformation of coupling beams within the values that can be met.
3. It prevents shear (brittle) failure.
4. It restricts damage to fragile non-structural elements, which can be costlier than the building.
5. Drift limitation provide stability of individual columns as well as the structure as a whole.
6. Limited drift also provide comfort to occupant of such buildings.

As per clause 7.11.1 of IS 1893 (part-I):2002, the storey drift in any storey due to specified designed lateral force with partial load factor of 1.0, shall not exceed 0.004 times the storey height.

Column Shear:

The present philosophy of the codes for SMR frames is to have yielding confined to the beams while the column remains elastic throughout the response, i.e., called strong column-weak beam concept. This philosophy leads to large size of members in preventing shear failure. Further, due to increase in axial load and horizontal shear column size and reinforcement become high. This tends to affect the cost of building. Hence, shear walls can be considered as a better option in soft storeys.

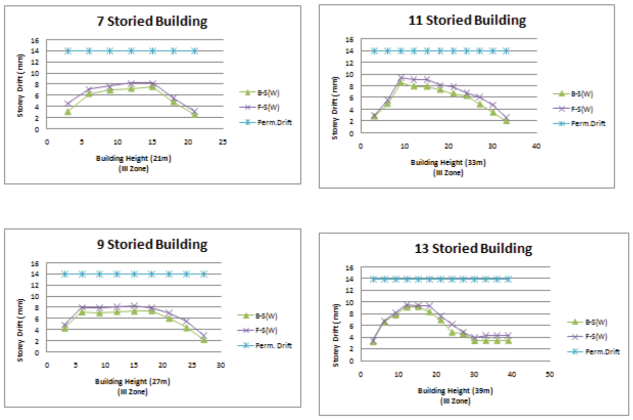

Figure.1 Shows Performance of Flat Slab V/S Two Way Slab using Shear Wall for Plan 16 m X 24 m for Zone III

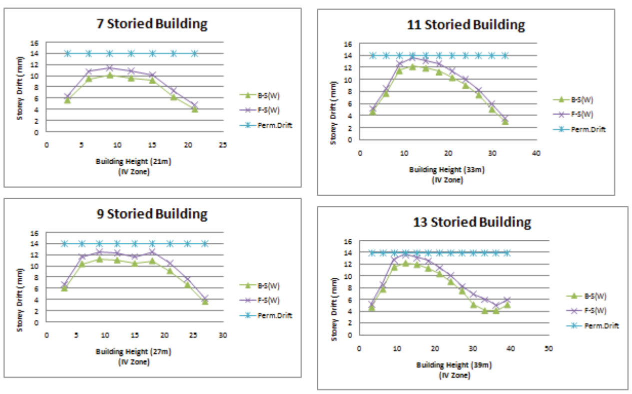

Figure.2 Shows Performance of Flat Slab V/S Two Way Slab using Shear Wall for Plan 16 m X 24 m for Zone IV

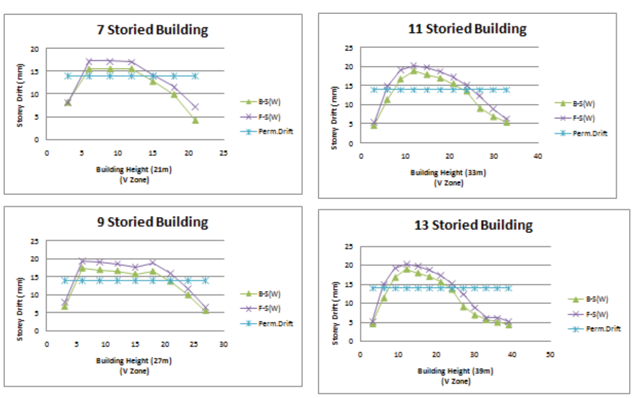

Figure.3 Shows Performance of Flat Slab V/S Two Way Slab using Shear Wall for Plan 16 m X 24 m for Zone V

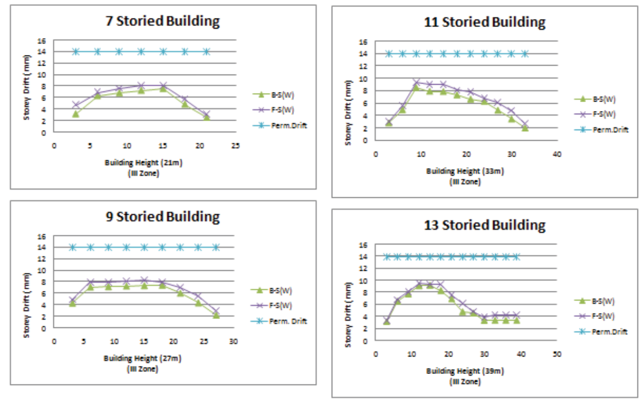

Figure.4 Shows Performance of Flat Slab V/S Two Way Slab using Shear Wall for Plan 15 m X 25 m for Zone III

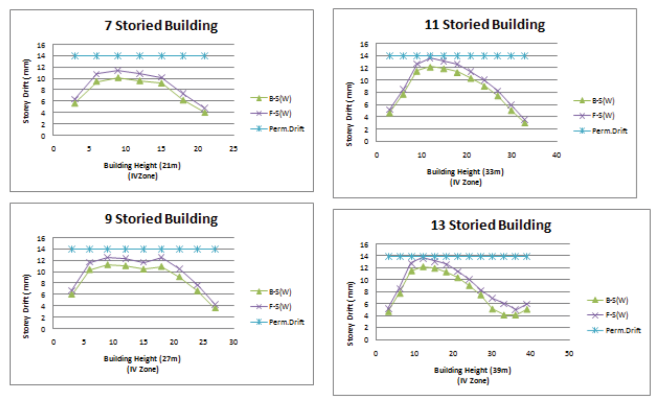

Figure.5 Shows Performance of Flat Slab V/S Two Way Slab using Shear Wall for Plan 15 m X 25 m for Zone IV

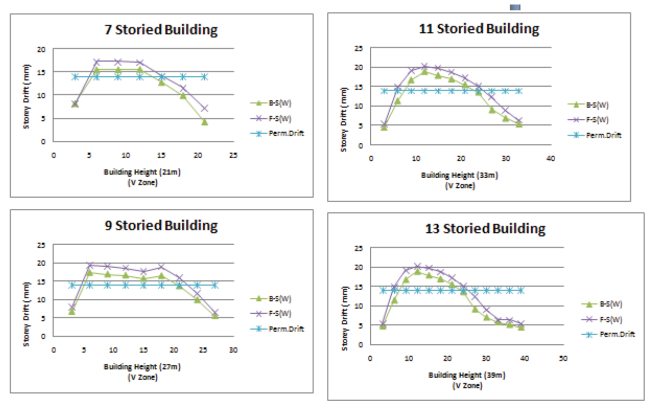

Figure.6 Shows Performance of Flat Slab V/S Two Way Slab using Shear Wall for Plan 15 m X 25 m for Zone V

IV.CONCLUSION

1. For all the cases considered drift values follow a parabolic path along storey height with maximum value lying somewhere near the middle storey.
2. Use of flat slabs with drop results in increase in drift values in shorter plans and decrease in larger plans, marginally in a range of 0.5mm to 3mm. Still all drift values are within permissible limits even without shear walls.
3. In zone III and IV use of flat slabs with drop in place of beam slab arrangements, though, alters the maximum displacement values, however, these all are well within permissible limits, even without shear walls.
4. Provision of part shear walls in zone V is not enough to keep maximum displacements within permissible limits, whether it is a beam slab framed structure or framed structure with flat slabs with drop.

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