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Analysis and Design of Transverse Post Tensioned Slab

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ABSTRACT

The current practice of design for a transfer plate–shear wall system in tall buildings does not generally include the interaction effect of the transfer plate and the supported shear walls on the structural behavior of the system. In this paper, we have considered G+45 floors for analysis and structural behavior of transfer plates supporting in-plane loaded shear walls are presented, For this post tensioned transfer plate analysis is carried out by using E-TABS, SAFE and RAPT software's. Shear wall loads which comes from above floors are taken from E-TABS model and same loads are executed in SAFE model for transfer plate behavior and analysis. Then after the strip forces (BM & SF) are taken from SAFE model to design the post tensioning transfer slab by using RAPT post tensioning design software.

Keywords : E Tabs, SAFE, RAPT, Flexural Design and Shear calculation

I. INTRODUCTION

Transfer plate is an element plate of structure sometimes used in high-rise buildings in major metro cities. Building design often involves a podium structure that houses other functional spaces such as a car parking or a large lift lobby which require an unobstructed spatial layout in order to give a more impressive view. While for the upper structure, it is often used as office or residential units using more economical shorter span design, or sometimes even with the putting in of very congested core wall for lift shaft and other building services. To achieve this result, the layout of the podium structure can use regularly spaced columns in longer span design. While the upper floor using columns, load bearing walls and central core arranged in a more congested layout can still be maintained. What it needs to do to accommodate the difference in loading is by the placing in of a transfer plate at the base of the tower structure, such that the loading of the upper floors can be taken up and transferred downward through the podium.

II. LITERATURE REWIEW

2.1 General

Extensive studies have been made on Transfers slab/beam with different load combinations to be considered. However, limited studies were done on the transfers slab/beam analysis. This study will be represent that the use of transfers slab in high rise buildings by using internal core walls.

2.2.1Omkar 1973, Worli – Mumbai

Consultant : BuroHappold Consultants
Contractor : L & T Constructions.
PT Area : 120000 Sq.mtr

Utracon's Involvement :PT Design & Execution ofSlabs 9 levels & Tower

Design and detailing of Post- tensioned slabs and beams for the Podium Level slabs (P03 – P12) of Zone A and Zone B. and 60 + Floors in Tower 1 And Tower 2.
Minimum Concrete cube compressive strength at 28 days shall be 50 N/mm2.
Minimum Concrete cube compressive strength at transfer shall be 30 N/mm2.
Minimum Concrete cube compressive strength for initial stressing shall be 9 N/mm2

<u>Un-Tensioned Steel</u>
Conventional/Un-tensioned reinforcement bars, having the following minimum Yield Strength shall be used

Flexure - 500 N/mm2 (Fe500)
Shear - 415 N/mm2 (Fe415)

Pre-Stressing Strand

Type of Strand : Class 2, Low relaxation seven ply Strand
Nominal Tensile Strength, f_y : 1860 N/mm^2
Diameter & Nominal Area : 0.5” (12.7 mm) & 98.7 mm^2
Specific Breaking Load : 183.7 kN
Serviceability Classification : 0.2mm crack width.
Type 3 – IS 1343:2012
System : Bonded.

Analysis and Design Software

The analysis and design will be carried out using the Finite Element software “ADAPT Floor Pro” and RAPT. This ADAPT FLOOR PRO 3-dimensional software is capable of carrying out the analysis and design of Post-tensioned floor plate in accordance to the latest prevailing codes. It analyses and designs individual floor level one at a time.

2.2.3 Sandwich-Class Housing Development

- Designer. JMK Joseph Chow & Partners LTD. WSL International LTD., Bern, 1996 - Contractor: Yau Lee Constructions COLTD. Hong Kong, 1996
In early 1995, the Hong Kong Housing Board made enquiries into the feasibility of utilizing pre-stressed transfer plates for the "Sandwich-Class' housing development of 3 residential blocks in north Ap Lei Chau.

III. METHODOLOGY

3.1 Introduction

In order to analyze the stress behavior of the shear wall-transfer slab Structure, the finite element method is employed throughout the research. Two Dimensional analysis is carried out and plane stress element is used to represent both the shear Wall and transfer beam element. Linear-elastic concept is employed instead of the more ideal non-linear. Analysis for the purposes of achieving an adequate level of performance under ordinary serviceability condition. Linear elastic analysis simply means that the design is based on the uncracked concrete structure and that the material is assumed to be linearly elastic, homogeneous and isotropic. It is adequate in obtaining the stress distribution for preliminary study or design purpose. A finite element model comprises shear Wall and transfer beam from a case study will be created using SAFE software. Throughout this paper, the SAFE Finite Element system is employed to carry out analysis on the Vertical stresses, horizontal stresses, shear stresses and shear force, bending moment in beam under the vertical gravity loads.

3.2 SAFE Finite Element System

A complete finite element analysis involves three stages: Pre-Processing, Finite Element Solve and Results-Processing. Pre-processing involves creating a geometric representation of the structure, then assigning properties, then outputting the information as a formatted data file (.FDB) suitable for processing by SAFE. To create model for a structure, geometry (Points, Lines, Combined Lines, Surfaces and Volumes) has to be identified and drawn. After that attributes (Materials, Loading, Supports, Mesh, etc.) have to be defined and assigned. An attribute is first defined by creating an attribute dataset. The dataset is then assigned to chosen features. Once a model has been created, the solution can be done by clicking on the results button. SAFE creates a data file from the model and solves the stiffness matrix, which finally yields the stresses sustained by the structure under loading in the form of contour plots, undeformed/deformed mesh plots etc.Then these results will be taken and imported for the ultimate design for the transfer beam or slab in the RAPT DESIGN software.

3.3.4.1 Deflection

Deformation in deep Slab/beams such as transfer slab/beam is normally not significant. The total deflection due to all loads should not be greater than 20mm.

3.3.4.2 Crack Width

The minimum percentage of reinforcement in a deep beam should comply with the requirements of tensile stresses limits.

3.5 Design codes used for the present study

IS 456-2000 Plain and Reinforced Concrete - Code of Practice
IS 1343-2012 code of practice for pre-stressed Concrete
IS 875-1987 (1, 2) Code of Practice for design loads
IS 1893 (Part 1):2002 Criteria for Earthquake Resistant Design of Structures

3.6 DESIGN BASIS FOR POST TENTIONED BEAMS/SLABS

The following major considerations to be taken for the designing of transfer slab

Design Codes

a) IS 1343: 1980 Code Of Practice For Pre-stressed Concrete.
b) IS 456 : 2000 Plain And Reinforced Concrete – Code of Practice.

Material Specification

a) Concrete :M50Should not be less than 25 N/mm^2
b) Hot Rolled Steel Bars 'T' : f_y= 500 N/mm^2
Hot Rolled Steel Links 'T' : f_y= 500 N/mm^2
c) Pre-stressing Steel System :USS-DSI Bonded Post tensioning System
Strand Properties : 7 Wire Super relaxation Class 2,
Type : BS 5896
Nominal Tensile Strength, f_y : 1860 N/mm^2
Diameter : 0.6" (15.2 mm)
Nominal Area : 140 m^2
Specific Breaking Load : 260.7kN
Friction Parameters : μ = 0.2/rad
k = 0.0017/m
Serviceability Classification : Class3 Member, 0.2mm crack width

DESIGN PARAMETERS

Basic Design Stresses
At Service
Design Compressive Stress : 0.33 f_{cu}
Design Comp.Stress over support : 0.40 f_{cu}
Design Hypothetical Flexural Stress : As per Table of The BS8110

Above basic design hypothetical flexural stress is to be modified by the coefficients in BS 8110, Table 4.3 based on the member's depth. The modified design hypothetical tensile stress may be increased by 4.0 N/mm^2 up to a limit of 0.25 fcu for every 1 % (of the cross-sectional area of the concrete in the tension zone) of additional reinforcement.

At Transfer

Design Compressive Stress : **0.50 f_{ci}**
Design Hypothetical Flexural Stress: **$0.36(f_{ci})^{1/2}$**
Characteristic Concrete cube strength at 28 days : **fcu**
Characteristic Concrete cube strength at transfer of pre-stress : **fci**
b) Basic Shrinkage Strain : 300 x 10^6 (Cl 4.8.4, BS 8110)
c) Basic Creep Factor : 3.4 (Cl 7.2, BS 8110 Part 2)
d) Relative Humidity : 50% (for indoor Environment)

Loadings:

Super imposed load = 3 kN/m^2 (excluding self weight)

Live load = 10 kN/m^2

Floating column loads are taken as per ETABS Model.

LOAD COMBINATIONS

The various loads shall be combined in accordance with the stipulations in IS: 875 (Part 5) – 1987. Whichever combination produces the most unfavorable effect in the building, foundation or structural member concerned shall be adopted.

Following load combinations of the member forces will be considered for arriving at the design forces. For this design considerations we consider the various combinations are given in the SAFE design software report.

Table : Values of Partial Safety Factor Δ_f for Loads

Load Combination	Limit State of Collapse				Limit State of Serviceability			
	DL	LL	WL/EL	TL	DL	LL	WL/EL	TL
DL + LL	1.5	1.5	--	--	1.0	1.0	--	--
DL + WL	1.5 or $0.9^{\$}$	--	1.5	--	1.0	--	1.0	--
DL+ LL ± WL	1.2	1.2	1.2	--	1.0	0.8	0.8	--
DL ± EL	1.5 or $0.9^{\$}$	--	1.5	--	1.0	--	1.0	--
DL + LL ± EL	1.2	1.2	1.2	--	1.0	0.8	0.8	--
DL+TL	1.5	--	--	1.5	1	--	--	1
Dl+IL ±TL	1.2	1.2	--	1.2	1	--	--	1
Dl+IL +TL± WL	1.2	1.2	1.2	1.2	1	1	1	1
Dl+IL +TL± EL	1.2	1.2	1.2	1.2	1	1	1	1

IV. ANALYSIS RESULTS AND DISCUSSION

In order to analyze the behavior of transfer Slab/beam due to the interaction between transfer beam and shear Wall, a 3D finite element model, representing a 45-floors high rise shear Wall structure, is created with the aid of ETABS 2015 software. In this section, the stress behavior of the transfer beam under superimposed loading, live load, Wind load and earth quake load will be obtained from the finite element analysis and presented in the graphical and tabular format. In order to verify these behaviors then we export to the all results like Bending Moment & Shear Forces in to the RAPT software. It will be used as guidance for comparison. With the bending moment and shear stress thus obtained, it is possible to design the transfer slab/beam.

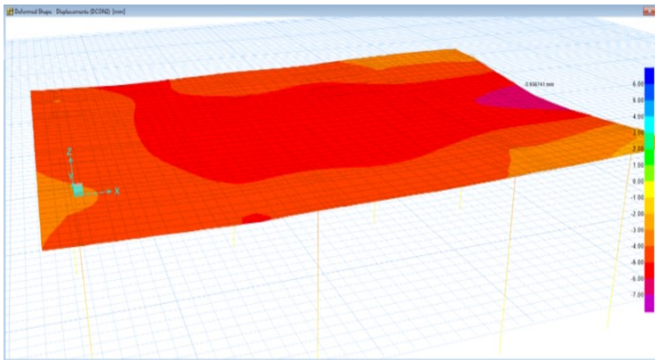

Figure 1 : Deformed shape

Figure 2 : Bending Moments of transfers beam Load

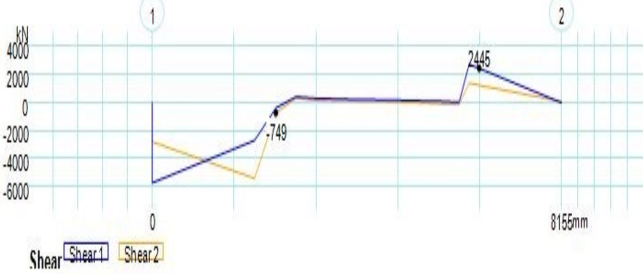

Figure 3 :shear forces of transfers beam Load

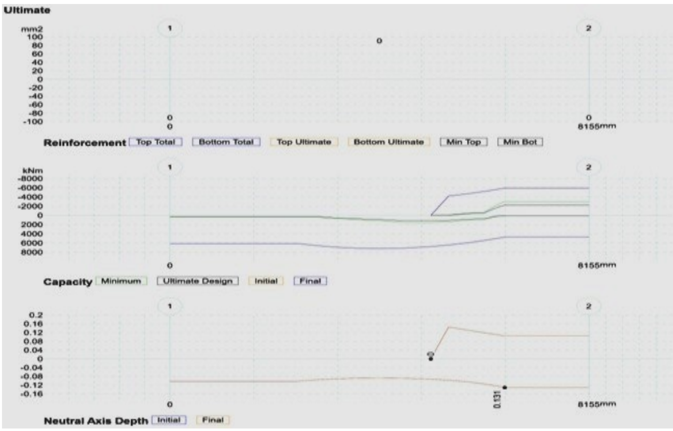

Figure 4 : Flexural Design

Checking the Transfers slab one way shear			
Factored Shear force	=	2200	kN
Breadth of slab	=	1000	Mm
Effective Depth of slab	=	1750	Mm
Nominal Shear Stress (λv)	=	1.257	N/mm2
Ast = Provided Rebar	=	2512	mm2
100ASt/bd	=	0.15	
Shear Stress Of Concrete (λc)	=	0.3	N/mm2
(λv- λc)	=	0.96	

$$Vus = \frac{0.87*fy*Asv*d}{Sv}$$

Assumed spacing	=	300mm		
Vus	=	1684040 N		
Asv	=	1046mm2		
Sv	=	473mm	Required > Provided	300mm

TYPICAL MANUAL PUNCHING SHEAR CALCULATION

PUNCHING SHEAR CHECK @ d/2			
REACTION R	=	24066	kN
Effective Depth of slab(d)	=	2050	Mm
column size (X)	=	400	
column size (Y)	=	3000	
PERIMEETER (P)	=	10500	Mm
Nominal Shear Stress (Tv) (1.4(v/pd))	=	1.565268293	N/mm2
GRADE OF CONCRETE(Fck)	=	50	N/mm2
Ks	=	0.64	
square root fck	=	7.071067812	
PERMISSIBLE SHEAR STRESS (Tc)	=	1.13137085	
Tc max	=	1.697056275	
shear reinforcement			
Asv	=	60941.90937	
Number of T20 LINKS Required	=	195T20	REQUIRED

PUNCHING SHEAR CHECK @ d			
REACTION R	=	24066	kN
Effective Depth of slab(d)	=	1750	mm
column size (X)	=	400	
column size (Y)	=	3000	
PERIMEETER (P)	=	13600	mm
Nominal Shear Stress (Tv)	=	1.415647059	N/mm2
GRADE OF CONCRETE(Fck)	=	50	N/mm2
Ks	=	0.64	
square root fck	=	7.071067812	
PERMISSIBLE SHEAR STRESS (Tc)	=	1.13137085	
Tc max	=	1.697056275	
shear reinforcement			
Asv	=	57520.06484	
Number of T20 LINKS Required	=	184T20	REQUIRED

PUNCHING SHEAR CHECK @ 1.5d			
REACTION R	=	24066	kN
Effective Depth of slab(d)	=	1750	mm
column size (X)	=	400	
column size (Y)	=	3000	
PERIMEETER (P)	=	16900	Mm
Nominal Shear Stress (Tv)	=	1.139218935	N/mm2
GRADE OF	=	50	N/mm2

CONCRETE(Fck)			
Ks	=	0.633333333	
square root fck	=	7.071067812	
PERMISSIBLE SHEAR STRESS (Tc)	=	1.119585737	
Tc max	=	1.679378605	
shear reinforcement			
Asv	=	49755.76685	
Number of T20 LINKS Required	=	159T20	REQUIRED
PUNCHING SHEAR CHECK @ 2d			
REACTION R	=	24066	kN
Effective Depth of slab(d)	=	1750	mm
column size (X)	=	400	
column size (Y)	=	3000	
PERIMEETER (P)	=	20400	mm
Nominal Shear Stress (Tv)	=	0.943764706	N/mm2
GRADE OF CONCRETE(Fck)	=	50	N/mm2
Ks	=	0.633333333	
square root fck	=	7.071067812	
PERMISSIBLE SHEAR STRESS (Tc)	=	1.119585737	
Tc max	=	1.679378605	
shear reinforcement			
Asv	=	40734.03924	
Number of T20 LINKS Required	=	130T20	REQUIRED

V. CONCLUSION

1).At the interface of the transfers beam and shear wall structure suffers from compressive stress at the area near supports and suffers from tensile stress at mid span.
2).The distribution of vertical stress on the transfers slab does not approach constant distribution pattern due to the existence of lateral loads in the form of shear walls.
3).The shear Wall is subjected to compressive horizontal stress throughout the stretch to counter the lateral loads from other direction. As for the transfer beam, the lower half of the beam suffers from tensile stress while the upper half suffers from compressive stress.
4).The maximum shear force in the transfer beam occurs at the column Zones. The effect of load contributes to an asymmetrical shear force distribution along the beam.
5).The positive bending moment occurs along the clear span of the beam and increases from left to right. The maximum bending moment does not occur at the mid-span of the beam, but culminates at a section just adjacent to the column face, which is the end of the transfer beam's clear span

VI. SCOPE OF FURTHER STUDY

The study presented here should be extended with varying heights. The performance of structures to wind loads should be studied and compared. The Study can be extended to the structure with only using transfers slab without using any concealed beams (transfers beams) and without drop panels. This work can be extended to symmetrical and unsymmetrical buildings considering deflections and the torsional provisions. The study presented here should be only the wind x-direction and wind-y-direction but this can be extended varying heights with various wind forces like wind xy-direction, wind guest x and wind guest y-directions. For this study the parking levels considered below the transfers slab level In further study parking levels can be introduced at different floor heights.

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