Optimization in Design of Elevated Service Reservoir by Limit State Approach

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***Abstract*:- The conventional working stress method of design as per IS 3370 is considered to be widely adopted method of design for liquid retaining structures, however new provisions in Indian standards allows limit state design with limitation on crack width.**

The main aim of the present study is to check efficiency and economy in design of water tank using limit state approach. The serviceability criteria for crack width may be crucial for working out final cross sectional properties and reinforcement in limit state design.

A medium capacity rectangular water tank having capacity of 1000 cum is considered for the study. The water tank has been modeled using finite element software ETABS. The analysis of water tank has been carried out for gravity and hydrostatic forces. The detailed design for each elements was performed using two methods of design namely WSM and LSM. The limit state design of water tank has been performed as per conventional methods for strength and serviceability. For serviceability check for crack width limitation of 0.2mm has been adopted for medium exposure condition as per clause 35.3.2 of IS 456:2000. Only the elements in contact with water have been checked for crack width criteria. The section design by WSM is considered as uncracked section and all relevant checks has been applied.

The findings in the present study suggest that the limit state design will be far more economical than working stress design in view point of reduction in thicknesses of various elements. There will be around 40 to 50% reduction in thicknesses can be achieved using limit state method which in turn reduces overall weight of tank. The reduction in weight reduces seismic forces on tank and improves lateral stability. The only drawback found in limit state design is small increase in reinforcement ratios for some of the elements which may be because of serviceability check for crack width. The crack section design may also lead to higher demand for waterproofing work. It is suggested to adopt proper admixtures along with membrane type waterproofing to overcome leakage problems for tanks design using limit state approach.

Keywords: Elevated service reservoir, Optimization, LSM, ETABS

I. INTRODUCTION

Elevated service reservoir is considered as single degree of freedom system with lump mass at top. The staging will be the flexible element and stiffness of staging plays an important role in overall stability of tank. The conventional method of design of water tank which include uncracked section has been widely used in India which insures water triteness and prevent leakages. The problem associated with uncracked section is at that the uncracked section yield huge thicknesses of elements and ultimately increases the overall weight of water tank. The increase in mass of tank also increases the lateral seismic forces and hence affects the overall stability of water tank. The limit state approach insures minimum section dimensions and hence minimum mass.

The overall performance of water tank depends on various parameters such as staging configuration, staging height, seismic weight, container aspect rations (for rectangular tanks) and weight of container etc. The overall mass of tanks plays an important role in behavior of tank. Lesser the mass better will be the performance. The current revisions in design standards allows design of water tank with limited crack width and hence the optimistic design can be achieved by using limit state approach over working stress approach.

II. METHODOLOGY

The moderate capacity rectangular elevated service reservoir has been selected for the analytical study. The capacity of the tank is considered as 1000 cum. Staging and geometry of the container is kept symmetrical. The tank is modeled by finite element software ETABS. The beams and columns are modelled as two dimensional beam elements with six degrees of freedom at each node. The slab is modeled as shell elements with six DOF at each node. The hydrostatic loading is applied on tank walls along with usual gravity load. The tank is analyzed for two conditions namely 1) Tank full and 2) Tank Empty. The result obtained from analysis are used for design of tank by WSM and LSM. Finally based on design output and section properties two methods are compared for concrete consumption and reinforcement. The mathematical model for the tank is shown in following figure-1

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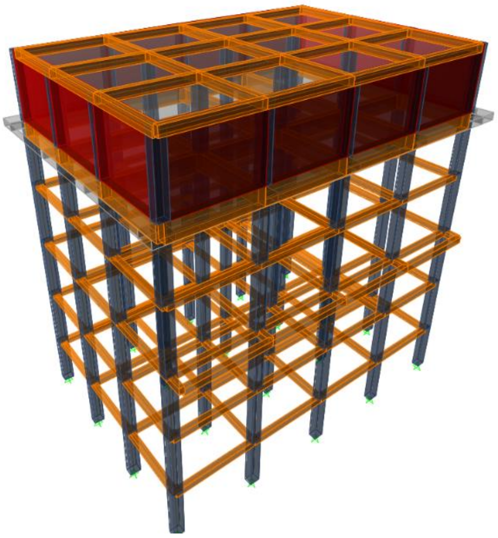

Fig -1: 3D-Mathematical model

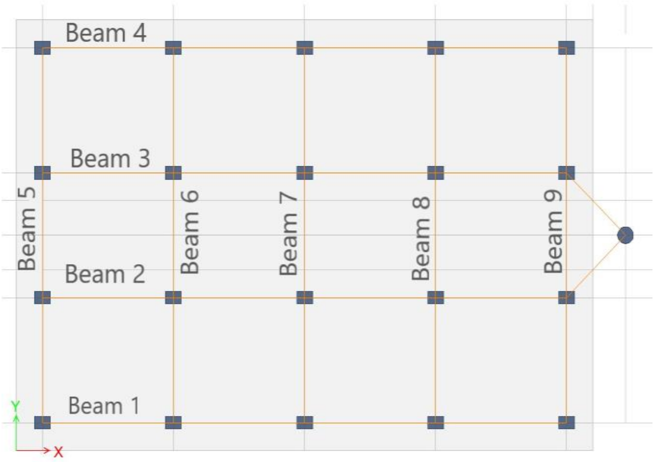

Fig -2: Plan at base slab level

III. ANALYSIS OF TANK

The tank is analyzed by ETABS software for the two loading conditions namely 1) Tank full and 2) Tank Empty. The hydrostatic load is applied on walls as area load laterally along with gravity load. The results obtained from analysis are extracted for critical load combinations for flexure and shear. The data used for analysis are shown in table -1 below

Table -1: Data used for analysis

Sr. No	Description	Specification
1	Structure	Elevated service reservoir
2	Depth of foundation	1.5m
3	Plan dimensions	20.4m x 13.9m
4	Live load intensity on top slab	1.5 KN/sqm
5	Finishing load on top slab	1.0 KN/sqm
6	Finishing load on floor slab	1.5 KN/sqm
7	Hydrostatic load on base slab	44.145 KN/sqm
8	Live load intensity on projected slab	3.0 KN/sqm
9	Grade of concrete	M40
10	Grade of steel	Fe500

IV. LOAD COMBINATION:

The tank is analyzed by ETABS software for the two loading conditions namely
i)Tank Full C_1 condition(DL+LL+WL)
ii) Tank empty C_2 condition (DL+LL)

V. ANALYSIS RESULT FOR ONE TYPICAL ELEMENT ARE SHOWN IN FIG

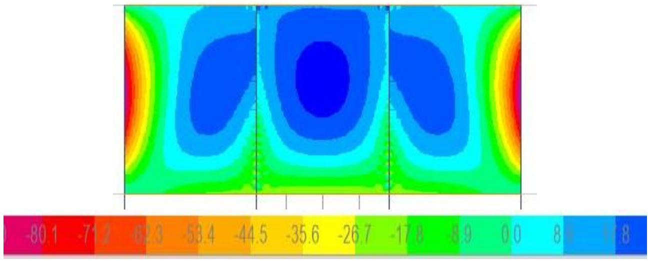

Fig -3: Bending moments M11 for short wall (C1 condition)

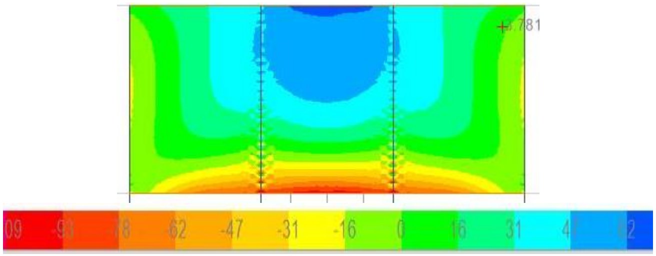

Fig -4: Bending moments M22 for short wall (C1 condition)

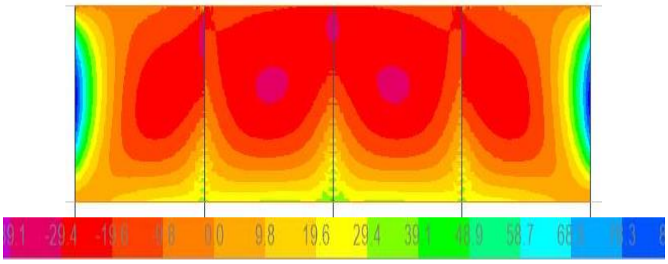

Fig -5: Bending moments M11 for long wall (C1 condition)

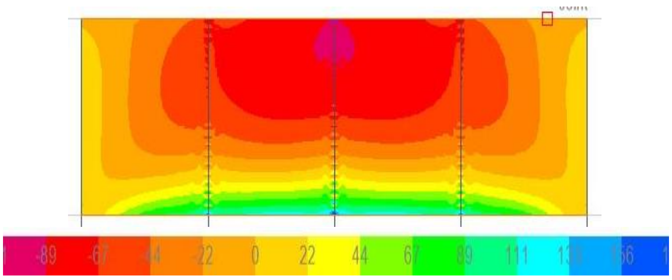

Fig -6: Bending moments M22 for long wall (C1 condition)

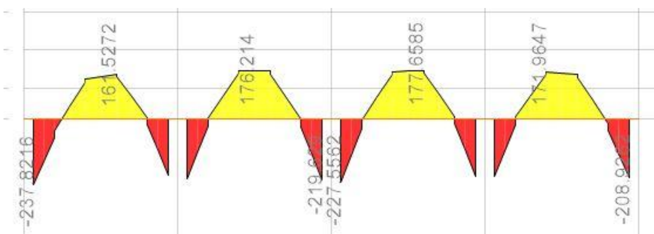

Fig -7: Bending moments for Beam 2 (c1 condition)

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VI. DESIGN OF TANK

The design of water tank is carried out for all elements as per two methods of design namely WSM and LSM. Design of base Slab, walls, beams are carried out as per Indian Standard specification for Limit State design the elements which are in contact with water are checked for cracked width of 0.2mm (As per IS456:2000 Clause 35.3.2).the sectional sizes and reinforcement obtain from design are tabulated below

Table -2: cross sectional dimensions (mm).

SR. NO.	Structural Elements	Working Stress method	Limit state method
1	Wall	450	300
2	Base Beam	1350	600
3	Roof Beam	1060	450
4	Slab	500	300

Table -3: Quantity of concrete (cum)

SR. NO.	Structural Elements	Working Stress method	Limit state method
1	Wall	162.06	108.04
2	Base Beam	25.82	11.47
3	Roof Beam	20.27	8.6
4	Slab	189	153.9

Table -4: Reinforcement Index (kg/cum)

SR. NO.	Structural Elements	Working Stress method	Limit state method
1	Wall	40.25	46.10
2	Base Beam	37.68	50.24
3	Roof Beam	32.5	44.2
4	Slab	27.63	29.81

Table -5: Crack width at various location

SR. NO.	Structural Elements	Location	Crack Width (mm)
1	Long Wall	Corner section inner side	0.182
2	Short Wall	Corner section inner side	0.175
3	Beam at base slab level	At top of beam	0.186
4	Base Slab	At top of slab	0.18

VII.RESULT AND DISCUSSION

The modeling, analysis and design, the water tank for the typical volume and the typical shape (L/B ratio = 1.5) was carried out using WSM and LSM. The design has been performed for the two condition as

a) C1 condition- Full tank condition (DL+WL+LL)

b) C2 condition- Empty tank condition (DL+LL)

The result obtained from the design of various elements are presented below for the critical load combination.

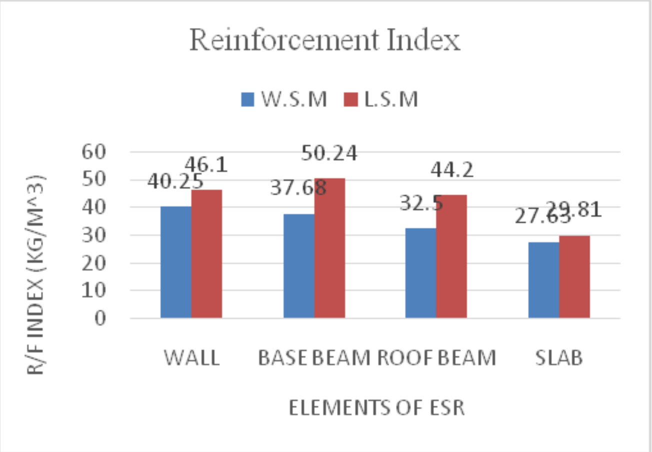

Chart -1: comparison of Reinforcement Index

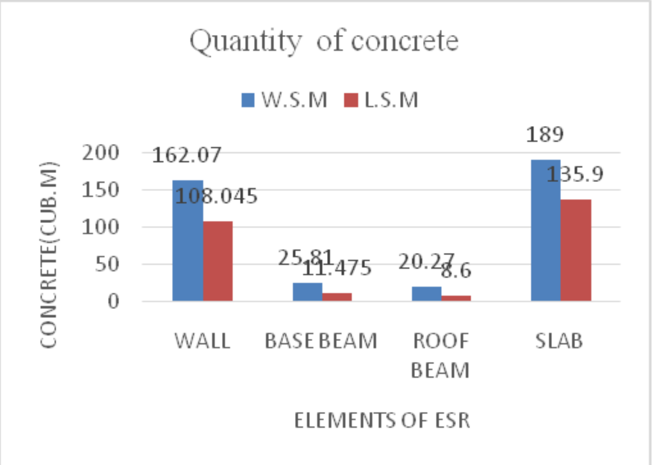

Chart -2: comparison of Quantity of concrete

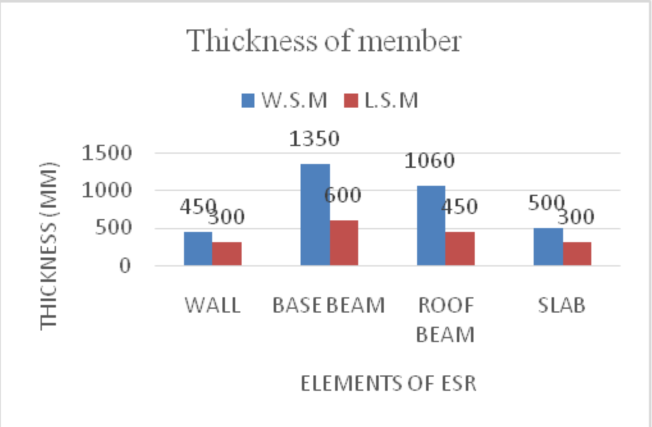

Chart -3: comparison of Thickness

VIII. CONCLUSIONS

Based on a study perform on typical water tank having volume of 1000m3 following conclusions are drawn-

1) It is observed that the water tank design using LSM proves to be more efficient and economical than WSM. Considerable reduction in thickness and overall volume of tank can be achieve using LSM. The reduction in thickness and overall volume will result in less seismic weight and better seismic performance of tank, however the amount of reinforcement required for LSM is more

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than WSM to satisfy crack width requirement as per Indian standards.
2) The reinforcement index for wall designed using LSM, is found to be 12.68% more than WSM.
3) There is considerable increase in reinforcement index was observed in beams at base slab level and at roof level for designed performed using LSM.
4) The reinforcement index for slab designed using LSM is found to be 7.31% more than WSM.
5) The thickness of wall, base slab and roof slab designed using LSM is around 46.72% less than WSM.
6) The concrete for wall designed using LSM is found to be 33.33% less than WSM.
7) There is considerable increase in concrete was observed in beams at base slab level and at roof level for designed performed using WSM.
8) The Concrete for slab designed using WSM is found to be 28% more than LSM.

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