SEMINAR

DUAL SYSTEMS

1-Research topic:

The performance of the Dual systems (frames and walls) in resisting earthquakes, and the efficiency of neglecting the shear walls and depending completely on the frames in resisting the seismic loads in spite of existence of shear walls.

2-Introductory

As it is well known to most of structural engineers who are familiar with the types of structural systems for resisting wind and seismic loads, they are called Shear systems- such as:

1-Frames:

- This is a frame system of rigid beams subjected to lateral loads where the developed moments in the middle of the columns are not existent.
  And the shear forces will be distributed proportionally with the moment of inertia of the columns and the lateral displacements will be proportional to these forces.

2-Shear walls:

- These systems resist the lateral loads with the shear walls whether these walls are separated or connected by beams.
  The distribution of shear forces is proportional to the moment of inertia of the cross sections of the walls; the displacements in each floor or level are the result of the Flexural deformations in the walls.

3-Dual systems

- These systems are the result of combining the two latter systems to resist the lateral load, in these systems the shape of the deformations will differ from those in frames and walls systems, where effecting interacted forces occur and change the shape of shear and moment diagrams. One of the advantages of this combination is that the frames support the walls at the top and control their displacement. Besides, the walls support the frames at the bottom and decrease their displacement.

In other words, the shear force of the frames is bigger at the top than it is at the bottom and it goes the other way round for the walls.

- We rarely find shear systems as complete shear walls without regular frames (beams and columns), or absolute frames without service walls or elevator walls.
- It has been mentioned in the international and local codes that in case we have regular frames of beams and columns along with shear walls to resist the lateral loads, the resistance of these members (the frames) to the lateral loads can be neglected, and it will be considered in the calculations only to resist the vertical loads, but we should conform to the codes conditions relating to the minimum reinforcement and the allowed displacement of these beams and columns.
- And the purpose of our research is to find out if we can neglect the presence of walls (concrete or masonry) if they are together with the frame system, where the frame system resists all the lateral shear forces, and the walls will be considered just to bear the vertical load, and what are the provisions for these walls and their effect on the frames load.
- We will find the proper answer throughout our research and experiments in this subject, and you can find the summary of the research in the results and recommendations page…

Best regards

Dr. Youssef Hamida

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The reasons and the cause for choosing this research and its importance, and whether it is done to fulfill an engineering need or to solve an engineering problem that helps in developing the engineering work.

3- **Research topic Demonstration:**

3.1 The Dual system is the one that both shear walls and frames participate in resisting the lateral loads resulting from earthquakes or wind or storms, and the portion of the forces resisted by each one depends on its rigidity, modulus of elasticity and its ductility, and the possibility to develop plastic hinges in its parts.

Knowing that the frame is a group of beams and columns connected with each other by rigid joints that can resist shear and moments, and the shear wall is considered as a cantilever free on the top and fixed in the bottom.

3.2 The structural resisting system might be only shear walls for resisting the lateral load and we can neglect the regular frames.

3.3 The structural resisting system might be only frames for resisting the lateral load and it is called Moment Resisting Frames.

- ❖ In the case of shear walls with the moment resisting frames, can we neglect the effect of these walls, and calculate the frames to resist the whole base shear.
- ❖ this is the subject of our research; the existence of some shear walls with moment resisting frames, could it be neglected and not taken into consideration for resisting the lateral loads, which means to calculate them only as gravity loads resisting members, and what are structural effects and changes resulting from that.

4.Purpose and benefit of the research

Some complains and questions had come to the Engineering Union-Civil Engineering department, about invalidating some domestic and industrial buildings licenses where some structural notes are present, and when there is a contradiction between the structural requirements for the buildings and the building manners or systems of the city municipality where:

4.1 Elevator and service walls must be of reinforced concrete, and that is to comply with the mechanical study, fire resistance, and more other reasons.

4.2 Also to conform to the structural provisions of the city municipality, the stair house walls should be of reinforced concrete instead of using masonry walls, and because of the door openings and piers are in small dimensions, it should be of reinforced concrete to bear the vertical loads.

4.3 Since most of the industrial buildings, stores, shops and halls or galleries are in the lower floors (base), shear walls can't be used to resist the seismic loads, so it is preferred to use moment resisting frames.

4.4 Repeating the structural study with taking into consideration the seismic study, and including these walls in the study will cause increment in the base shear because of decrement in (R); the Elastic Modulus of the structural system.

In addition, the use of computers, 3d modeling, and advanced programs might be a little hard to procure in regular or individual offices.

4.5 That's why we needed to make researches and investigations about a method or a study of possibility of neglecting the shear or masonry walls and not considering them as participants with the frames. Also neglecting the regular frames and not considering them as participants with the shear walls, and considering them as gravity loads resisting members but with other conditions that we will see in the results of our research.

5-<u>The determined basics for making the research:</u>

To define the relationship and the effect of the shear walls on the function of the moment resisting frames, and to know if these walls can be studied only for resisting the gravity loads not the lateral load.

5.1 It was necessary to go back to the theories and hypothesizes of the interactive performance between frames and walls, and we needed to seek the help of the theory of Professor (Lain Macleod). The calculations and results have been checked by the computer depending on the international program (ETABS). Due to the enormous number of analysis's and experiments according to the variety of floors and walls number and dimensions of cross sections of the columns. We depended on a local program (STAAD-ALARAB) for calculating the frames and the shear walls depending on the theory and assumptions of Professor Macleod relating to the interacted performance between the frames and the walls. The summary of this theory as it came in the research symposium of Portland Cement institution:

5.2 The dual system is the one that both frames and shear walls contribute in resisting the lateral loads, where the frame is a group of beams and columns connected with each other by rigid joints, and the frames bend in accordance with (Shear Mode), whereas the deflection of the shear walls is by a (Bending Mode) like the cantilever walls.

5.3 As a result of the difference in deflection properties between frames and walls, the frames will try to pull the shear walls in the top of the building, while in the bottom, they will try to push the walls, so the frames will resist the lateral loads in the upper part of the building, which means an increase in the dimensions of the cross section area of the columns in the upper part of the frame more than what it needs to resist the gravity loads, while the shear walls will resist most of the vertical loads in the lower part of the building.

5.4 So the distribution of the lateral loads in the top depends on the rigidity of the frames where we suppose a spring support, whose rigidity equals the rigidity of the frames in the top, and the reaction of this spring is the share of the frames, and the rest is the share of the walls. So, the walls are pinned or supported by the frames at the top and fixed at the bottom and they are resisting the seismic loads.

5.5 So we need to find out the value of this reaction at the top which equals a point load as the share of the frames according to the (Macloed Theory), then the share of the frames will be distributed to each frame due to its rigidity and position relating to the center of mass taking into consideration the torsion and shear resulting from torsion.

And that is according to the laws and relations and factors mentioned below:

6-Terminology:

Ac: cross section area of columns

B: length of the frame

C: width of column

D; depth of the beam

E: Young Modulus

Fg, Fm, Fn, FS: functions depending on the shape of the seismic load

$$Fg = \frac{Moment\ of\ inertia\ of\ the\ upper\ floor}{Moment\ of\ inertia\ of\ the\ lower\ floor} \quad \ldots\ldots\ldots\ldots 7$$

H: total height of the wall

h: height of the column in every floor

I_b: moment of inertia of the beams in the nods or joints

I_w: moment of inertia of the walls

K_w: Shear rigidity of the walls

K_f: rigidity of the frames

$$m = \frac{Cross\ Section\ Area\ of\ columns\ in\ the\ upper\ part\ of\ the\ building}{Cross\ Section\ Area\ of\ columns\ in\ the\ lower\ part\ of\ the\ building} \ldots\ldots 7.1$$

$$S = \frac{Moment\ of\ Inertia\ of\ columns\ in\ the\ upper\ part\ of\ the\ frame}{Moment\ of\ Inertia\ of\ columns\ in\ the\ lower\ part\ of\ the\ frame} \ldots\ldots 7.2$$

$$Fs = \frac{log_e S}{S-1} \quad \ldots\ldots\ldots\ldots 7.3$$

W= total lateral load

$\Delta = total\ displacement\ in\ the\ top\ of\ the\ frame$

$\Delta_A = \ displacement\ for\ the\ axial\ loads\ in\ the\ columns$

$\Delta_B = \ displacement\ resulting\ from\ moment\ deflection$

$$\lambda = \frac{\sum \frac{E_c I_c}{h}}{2\sum \frac{E_b I_b}{l}} \quad \text{……….7.4}$$

$\Delta_w = \frac{H^3}{3EI}$ ………… the displacement of the wall……..7.5

$\Delta_f = \frac{P.h^2.H}{3EI}$ ………… the displacement of the columns……..7.6

$K_f = \frac{1}{\Delta_f}$ ………… rigidity of the frame

$K_w = \frac{1}{\Delta_w}$ ………… rigidity of the wall

$\frac{P}{W} = \frac{11/20}{1+\frac{\sum K_w}{\sum K_f}}$ ……………..7.7 where:

P: share of the frames

W: total shear force

Share of walls: $P_1 = W - P$

7-**Researches and experiments:**

- The research has been done and the data has been changed to follow the Second Static Method for calculating the Base Shear according to the Syrian Code and The American Code: (Uniform Building Code, UBC) according to the law:

$$V = \frac{C_v . I}{R . T} W$$

7.1 The local program (STAAD-ALARAB) and ETABS have been adopted to check and calculate the internal forces resulting from neglecting the shear walls.

7.2 Thirty five typical space and plane cases have been chosen. In every case, the constants and dimensions are changed to obtain the maximum stresses and forces and that is according to the tables, calculations and the results attached in the end of the research.

7.3 For the number of the floors, we studied from one floor cases till twelve floor cases.

-Three cases have been chosen to get maximum torsion and its effect on the frame, and that is by the types of the walls and their positioning with respect to the center of mass.

7.4 A case of one wall with frames different in rigidity has been studied, with different floors for different cases with eccentricities:

e = $l / 2$ e = $l / 4$ e = 0

7.5 Also the procedures are repeated for the case of two walls for different number of floors and different examples.

7.6 Also the procedures are repeated for the case of three walls for different number of floors, different types and rigidities of frames, and different eccentricities.

7.7 Also in the research, a case of only frames without shear walls has been studied, then we started to insert one shear wall, then we increased the number of walls to two then to three. Also for finding the eccentricity and increasing it to the maximum value predicted.

Through the research results and the attached tables, some important observations can be noted, and corrections to some wrong concepts can be done for the colleagues of engineers about the relation between the frames and walls.

7.8 The most significant observation and the correction to the wrong belief is that increasing the number of shear walls and duplicating its area doesn't duplicate the share of the walls, but it stays almost the same as there is only one shear wall, the increase is almost insignificant (about 15%) and it comes from the increase of base shear resulting from the increase in rigidity of the walls and the decrease of the dynamic period, which means that the frames takes its share from the base shear in the top then the rest is distributed (in the bottom) on the existed walls (one or two or three….etc.)

And that is what we observed in the research results, that is existing of a number of walls and then neglecting them is better and gives less shear and bending stresses than the case of one wall which is considered to be neglected.

7.9 We found out through the results that the frame's shear if there is no walls (the Moment resisting frames case) is bigger than what it is in the case of frames and neglected walls, because the torsion shear which is caused by the eccentricity of the neglected walls, and which is added to the peripheral frames' shear is smaller than the shear that the walls take from the peripheral frame with the maximum torsion.

7.10 We also noticed the increase of the base shear when there are walls rather than the case of no walls (only frames) and that is because of the decrease of the dynamic period for the increase in the rigidity of the Dual system and the decrease of the factor (R) in the denominator of the base shear law.

7.11 In the attached drawing of the (interactive-mutual) performance, we noticed that in the case of only two shear walls without a frame, the base shear is distributed equally in the top and bottom in the walls. And if there is one frame with those two walls, we see that the share of the walls is maximum in the bottom, and the share of the frame is zero in the top and the bottom but maximum at the height (0.8 H), and that is the hypothesis of Prof. Macloed, which is to put a constant point load equals to the maximum shear which occurs at the height (0.8-0.95) of the total height.

7.12 Referring back to the results table of the program STAAD-ALARAB and ETABS for the internal forces or stresses and reinforcement:

7.13 we notice that it is taken into consideration:

-the dynamic period, the static period, ductility factor (Rw), accidental eccentricity of walls positioning, ratio of frames and walls shares, modifying the value of ductility factor (Rw) according to that ratio, also calculation of the base shear V for every case and considering the maximum case.

7.14 we noticed from the table that the maximum share of the frames in case of no walls (Moment resisting frames) is larger than the case of frames with walls, for example:

8-**Comparison and results**:

Research example No#5:

Floor number: 7

The columns: 40 X 60

The walls: L=3,00 m

V= 61 t without walls

V= 44.46 t in case of one wall with maximum eccentricity

61 > 44.46 accepted

8.1 Also we notice from the results of ETABS:

That the shear and flexural stresses are maximum for one shear wall, also we noticed that the minimum reinforcement for shear and bending is adequate, so these walls can be neglected and designed only for the gravity loads, if the number of floors is less or equal to twelve floors.

8.2 We noticed when the number of the floors is more than twelve, and the minimum reinforcement is not adequate here, we differentiate two cases:

8.2-1 When the flexural reinforcement is not adequate, the walls are safe,

because when the walls enters the plastic situation, the frames will intervene and take the loads from these walls and the walls will crack but not collapse, or it will lose its rigidity and not resist any lateral loads.

8.2-2 When the shear reinforcement is not adequate,

these walls will collapse by shear, and its breaking will be brittle so it should it should be calculated, or we should neglect its resistance to the vertical loads by putting beams over them.

9-Results and recommendations:

9.1 It is possible to neglect the shear walls and do not consider them as participants with the moment resisting fames in resisting the lateral loads, and to consider that all the lateral loads as base shear or wind loads are going to be resisted only by the frames according to following conclusions:

9.2 The moment resisting frames is not affected by neglecting the shear walls when the walls do not take part with the frames in resisting the loads, on the contrary, the safety factor for the frames becomes bigger and the shear resisted by the frames is less than what it was when the frames were alone.

9.3 When the number of the building's floor is equal or less than 12 floors, ($n \leq 12$), the shear walls can be neglected provided that they are qualified to bear the only vertical loads, and the minimum reinforcement is adequate for flexural and shear.

9.4 When the number of the building's floor is more than 12 floors, ($n \geq 12$), it is possible to neglect the participation of the walls with the frames, provided that we should consider finding alternative members to the walls for resisting the vertical loads like beams or the frames itself, so when we put beams on top of the walls or any other structural members to transfer the vertical loads from these walls to the beams and columns. It is adequate to use the minimum reinforcement for flexural and shear stresses, because these walls will crack in the plastic phase, so the frames will intervene to defend these walls and take the lateral load (all the lateral loads will be resisted by the frames