Behavior of Multi-Story Building With and Without Shear Wall Under the Effect Wind Loads

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Abstract
Shear walls are specially designed structural walls that are incorporated in buildings to resist lateral forces that are created in the plane of wall due to wind, earthquake and flexural members. This paper presents the study and comparison of the distinction between the wind behaviors of buildings with and while not shear wall victimization Staad professional.

Keywords, Shear wall, STAAD PRO , Wind behavior

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1. Introduction
The high rise building represent the optimum like areas particularly in dense and expensive areas, together with excellence in execution and esthetically conjointly different considerations that everyone over the globe. Some high-rise buildings regarding the globe see Figure (1.1)

![Figure 1.1: some high-rise buildings about the world](image)

1.2 Structural Systems for Tall Buildings
The following classification is planned for the structural systems of tall buildings for all the categories specifically, steel buildings, ferroconcrete buildings, and composite buildings.[5]:
1. Rigid frame systems
2. Braced frame and shear-walled frame systems
3. Stabilizer systems
4. Framed-tube systems
5. Braced-tube systems
6. Bundled-tube systems

1.2.1 Rigid Frame Systems
Rigid frame systems are utilized in both steel and reinforced concrete construction. Rigid frame systems for resisting lateral and vertical loads have long been accepted for the design of the buildings. Rigid framing, namely moment framing, is based on the fact that beam-to-column connections have enough rigidity to hold the nearly unchanged original angles between intersecting components. Owing to the natural monolithically behavior, hence the inherent stiffness of the joist, rigid framing is ideally suitable for reinforced concrete buildings [5].

For a rigid frame the strength and stiffness are proportional to the dimension of the beam and the column dimension, and inversely proportional to the column spacing. Especially for the buildings constructed in seismic zones, a special attention should be given to the design and detailing of joints, since rigid frames are more ductile and less vulnerable to severe earthquakes when compared to steel braced or shear-walled structures. (Fig.1.2)
1.2.2 Braced Frame and Shear-Walled Frame Systems

Rigid frame systems are not efficient for buildings taller than 30 stories, because lateral deflection due to the bending of columns causes the drift to be too large. On the other hand, steel bracing or shear walls with or without rigid frame (brace systems and shear wall systems), increases the total rigidity of the building and the resulting system is named as braced frame or shear-walled frame system. Namely, systems composed of steel bracing or shear walls alone, or interacting with the rigid frames can be accepted as an improvement of the rigid frame system. These systems are stiffer when compared to the rigid frame system, and can be used for buildings over 30 stories, but mostly applicable for buildings about 50 stories in height. [5]

1.2.2.1 Braced Frame Systems

Braced frame systems are utilized in steel construction. This system is a highly efficient and economical system for resisting horizontal loading, and attempts to improve the effectiveness of a rigid frame by almost eliminating the bending of columns and girders, by the help of additional bracing. It behaves structurally like a vertical gravity loads, and diagonal bracing components so that the total set of members forms a vertical cantilever truss to resist the horizontal loading.

1.2.2.2 Shear-Walled Frame Systems

Resist lateral wind and seismic loads acting on a building and transmitted to them by the floor diaphragms. Shear walls are generally parts of the elevator and service corps, and frames to create a stiffer and stronger structure. These elements can have various shapes such as, circular, curvilinear, oval, box-like, triangular, or rectilinear. This system structurally behaves like a concrete building with shear walls resisting all the lateral loads. (Fig.1.3)
1.3. Tall building codes
- ASCE/SEI 7-10
- (2006 – 2009) IBC
- ACI 318 – 05 /08
- المسودة الأولية لمدونة الزلزال العراقية (م.ب.ع).

1.4 Difference between Law Rise Buildings and Tall Buildings
A tall- building is defined as a building 35 meters or greater in height, which is divided at regular intervals into occupiable levels. To be considered a high-rise building, an edifice must be based on solid ground and fabricated along its full height.[3] The cut-off between tall and low buildings is 35 meters. A low-rise building is defined as any occupable building which is divided at regular intervals into occupiable levels and which is lower than a high-rise, i.e., lower than 35 meters. To be considered a low-rise building, an edifice must be based on solid ground and fabricated along its full height and have at least one floor above the ground [3]. see (fig1.4) for law rise and tall building difference.

Figure 1.4: Tall and law buildings

2. Loads on High Rise Buildings
2.1 Loads
Structural members must be designed to support specific loads. Loads are those forces for which a given structure should be proportioned. In general, loads may be classified as dead or live.

2.1.1 Dead Load
Dead loads consist of the weight of all materials of construction incorporated into the building including but not limited to walls, floors, roofs, ceilings, stairways, built-in partitions, finishes, cladding and other similarly incorporated architectural and structural items, and fixed service equipment including the weight of railways.[1]

2.1.2 Live Load
Live loads are those loads produced by the use and occupancy of the building or other structure and do not include construction or environmental loads such as wind load, snow load, rain load, earthquake load, flood load, or dead load. Live loads on a roof are those produced:
- During maintenance by workers, equipment, and materials
- During the life of the structure by movable objects such as planters and by people.
  - The ACI Code does not specify loads on structures; however, IBC-2012 and the American National Standards Institute (ANSI) [5] prescribe occupancy loads on different types of buildings. Some typical values are shown in Table 2.1. Table 2.2 shows the density of various materials.
  - The live loads used in the design of buildings and other structures shall be the maximum loads expected by the intended use or occupancy but shall in no case be less than the minimum uniformly distributed unit loads required by Table (2-1).
| Occupancy or Use                                           | Uniform psf (kN/m²) |
|-----------------------------------------------------------|---------------------|
| Apartments (see residential)                              |                     |
| Access floor systems                                     |                     |
| Office use                                                | 50 (2.4)            |
| Computer use                                              | 100 (4.79)          |
| Armories and drill rooms                                  | 150 (7.18)          |
| Assembly areas and theaters                               |                     |
| Fixed seats (fastened to floor)                           | 60 (2.87)           |
| Lobbies                                                   | 100 (4.79)          |
| Movable seats                                             | 100 (4.79)          |
| Platforms (assembly)                                     | 100 (4.79)          |
| Stage floors                                              | 150 (7.18)          |
| Balconies (exterior)                                     |                     |
| On one- and two-family residences only, and not exceeding 100 ft² (9.3 m²) | 60 (2.87)           |
| Bowling alleys, poolrooms, and similar recreational areas | 75 (3.59)           |
| Catwalks for maintenance access                          | 40 (1.92)           |
| Corridors                                                 |                     |
| First floor                                               | 100 (4.79)          |
| Other floors, same as occupancy served except as indicated|                     |
| Dance halls and ballrooms                                 | 100 (4.79)          |
| Decks (patio and roof)                                   |                     |
| Same as area served, or for the type of occupancy accommodated |               |
| Dining rooms and restaurants                             | 100 (4.79)          |
| Dwellings (see residential)                              |                     |
| Elevator machine room grating (on area of 4 in² (2580 mm²)) |               |
| Finish light floor plate construction (on area of 1 in² (645 mm²)) |               |
| Fire escapes                                              |                     |
| On single-family dwellings only                           | 100 (4.79)          |
| Fixed ladders                                             |                     |
| Garages (passenger vehicles only)                         | 40 (1.92)           |
| Trucks and buses                                          |                     |
### Table 2.1 Typical Uniformly Distributed Design live Loads

| Occupancy or Use                                      | Uniform psf (lb/ft²) |
|-------------------------------------------------------|----------------------|
| Grandstands (see stadium and arena bleachers)         |                      |
| Gymnasiums, main floors, and balconies                | 100 (4.79) Note (4)  |
| Handrails, guardrails, and grab bars                  |                      |
| Hospitals                                              |                      |
| Operating rooms, laboratories                         | 60 (2.87)            |
| Private rooms                                          | 40 (1.92)            |
| Wards                                                  | 40 (1.92)            |
| Corridors above first floor                           | 80 (3.83)            |
| Hotels (see residential)                              |                      |
| Libraries                                              |                      |
| Reading rooms                                          | 60 (2.87)            |
| Stack rooms                                            | 150 (7.18) Note (3)  |
| Corridors above first floor                           | 80 (3.83)            |
| Manufacturing                                          |                      |
| Light                                                  | 125 (6.00)           |
| Heavy                                                  | 250 (11.97)          |
| Marquees and canopies                                  | 75 (3.59)            |
| Office buildings                                       |                      |
| File and computer rooms shall be designed for heavier  |                      |
| loads based on anticipated occupancy                   |                      |
| Lobbies and first floor corridors                      | 100 (4.79)           |
| Offices                                                | 50 (2.40)            |
| Corridors above first floor                           | 80 (3.83)            |
| Penal institutions                                     |                      |
| Cell blocks                                            | 40 (1.92)            |
| Corridors                                              | 100 (4.79)           |
| Residential                                            |                      |
| Dwellings (one- and two-family)                       |                      |
| Uninhabitable attics without storage                  | 10 (0.48)            |
| Uninhabitable attics with storage                      | 20 (0.96)            |
| Habitable attics and sleeping areas                    | 30 (1.44)            |
| All other areas except stairs and balconies           | 40 (1.92)            |
| Hotels and multifamily houses                          |                      |
| Private rooms and corridors serving them               | 40 (1.92)            |
| Public rooms and corridors serving them                | 100 (4.79)           |
| Reviewing stands, grandstands, and bleachers          | 100 (4.79) Note (4)  |
Table 2.2 Density of Various Materials

| Material                        | Density |
|--------------------------------|---------|
|                                | lb/ft³  | kg/m³  |
| Building materials             |         |        |
| Bricks                         | 120     | 1,924  |
| Cement, portland, loose        | 90      | 1,443  |
| Cement, portland, set          | 183     | 2,933  |
| Earth, dry, packed             | 95      | 1,523  |
| Sand or gravel, dry, packed    | 100–120 | 1,600–1,924 |
| Sand or gravel, wet            | 118–120 | 1,892–1,924 |
| Liquids                        |         |        |
| Oils                           | 58      | 930    |
| Water (at 4°C)                 | 62.4    | 1,000  |
| Ice                            | 56      | 898    |
| Metals and minerals            |         |        |
| Aluminum                       | 165     | 2,645  |
| Copper                         | 556     | 8,913  |
| Iron                           | 450     | 7,214  |
| Lead                           | 710     | 11,380 |
| Steel, rolled                  | 490     | 7,855  |
| Limestone or marble            | 165     | 2,645  |
| Sandstone                      | 147     | 2,356  |
| Shale or slate                 | 175     | 2,805  |
| Normal-weight concrete         |         |        |
| Plain                          | 145     | 2,324  |
| Reinforced or prestressed      | 150     | 2,405  |

2.2 Wind Load
Buildings and their components are to be designed to withstand the code-specified wind loads. Calculating wind loads is important in the design of the Wind force-resisting system, including structural members, components, and cladding, against shear, sliding, overturning, and uplift actions. See fig 2.1
2.2.1 Methods of Determination Wind Load

The design wind loads for buildings and other structures shall be determined according to one of the following procedures [ASCE7-10]:

(1) Method – Simplified procedure for low-rise simple diaphragm buildings.
(2) Method – Analytical procedure for regular shaped building and structures.

2.2.1.1 Method – Simplified Procedure

The simplified procedure is used for determining and applying wind pressures in the design of simple diaphragm buildings with flat, gabled, and hipped roofs and having a mean roof height not exceeding the least horizontal dimension or 60 feet (18.3 m), whichever is less, and subject to additional limitations.

2.2.1.2 Method – Analytical Procedure

Wind loads for buildings and structures that do not satisfy the conditions for using the simplified procedure can be calculated using the analytical procedure provided that it is a regular shaped building or structure, and it does not have response characteristics making it subject to a cross-wind loading, vortex shedding, instability due to galloping or flutter, or does not have a site location that require special consideration. [ASCE7-10]

Method 1 can’t use for determination of wind load due to building height (64m) and it use for building with law rise (<18.3 m) so we will be use method 2 for determine wind load.

2.3 Procedure for Determined Wind Load

2.3.1. Determine Velocity Pressure

Velocity pressure, qz, evaluated at height z shall be calculated by the following equation [ASCE7-10]:

\[ qz = K_d \times V \times K_z \times K_{zt} \]

Where:
- \(qz\) = velocity pressure
- \(K_d\) = wind directionality factor
- \(K_z\) = velocity pressure exposure coefficient
- \(K_{zt}\) = topographic factor defined
- \(V\) = basic wind speed

2.3.1.1. Determine \(K_d\)

\(K_d\) find from Table (2-3).
2.3.1.2 Find $K_{zt}$

$K_{zt}$ is found from

$$K_{zt} = (1 + K_1 K_2 K_3)^2$$

Where:

- $K_1$, $K_2$, and $K_3$ are given in Table (2-4) shown below. If site conditions and locations of structures do not meet all the conditions specified in Table (2-4), then $K_{zt} = 1.0$.

### Table (2-4)

| Hill Shape | $K_0/(H/L_0)$ | Exposure | $\gamma$ | $\mu$ |
|------------|--------------|----------|----------|-------|
| 2-dimensional ridges (or valleys with negative $H$ in $K_0/(H/L_0)$) | 1.30 | 1.45 | 1.55 | 3 | 1.5 | 1.5 |
| 2-dimensional escarpments | 0.75 | 0.85 | 0.95 | 2.5 | 1.5 | 4 |
| 3-dimensional axisym. hill | 0.95 | 1.05 | 1.15 | 4 | 1.5 | 1.5 |

**Notes:**

1. For values of $H/L_0$, $x/L_0$, and $z/L_0$ other than those shown, linear interpolation is permitted.
2. For $H/L_0 > 0.5$, assume $H/L_0 = 0.5$ for evaluating $K_1$ and substitute $2H$ for $L_0$ for evaluating $K_2$ and $K_3$.
3. Multipliers are based on the assumption that wind approaches the hill or escarpment along the direction of maximum slope.
4. Notation:
   - $H$: Height of hill or escarpment relative to the upwind terrain, in feet (meters).
   - $L_0$: Distance upwind of crest to the edge of the surface of highest ground elevation along the direction of maximum slope.
   - $K_1$: Factor to account for shape of topographic feature and maximum speed-up effect.
   - $K_2$: Factor to account for reduction in speed-up with distance upwind or downwind of crest.
   - $K_3$: Factor to account for reduction in speed-up with height above local terrain.
   - $x$: Distance (upwind or downwind) from the crest to the building site, in feet (meters).
   - $z$: Height above ground surface at building site, in feet (meters).
   - $\mu$: Horizontal attenuation factor.
   - $\gamma$: Height attenuation factor.
2.3.1.3 Find Kz

Kz find from equation below:-

1- The velocity pressure exposure coefficient Kz may be determined from the following formula or from the Table (2-5):

   For 15 ft. ≤ z ≤ zg
   
   \[ K_z = \frac{2.01(z/zg)^{2/\alpha}}{\alpha} \]

   For z < 15 ft.
   
   \[ K_z = \frac{2.01(15/zg)^{2/\alpha}}{\alpha} \]

2- α and zg in Table (2-6)

3- Linear interpolation for intermediate values of height z is acceptable

### Table 2.5 velocity pressure exposure coefficients, Kz and Kh

| Height above ground level, z | Exposure | B   | C   | D   |
|-----------------------------|----------|-----|-----|-----|
| ft                          | (m)      |     |     |     |
| 0.15                        | (0.46)   | 0.67| 0.85| 1.03|
| 20                          | (6.1)    | 0.62| 0.90| 1.08|
| 40                          | (12.2)   | 0.66| 0.94| 1.12|
| 60                          | (18.3)   | 0.70| 1.04| 1.17|
| 80                          | (24.4)   | 0.74| 1.09| 1.22|
| 100                         | (30.5)   | 0.78| 1.13| 1.27|
| 200                         | (61.0)   | 0.99| 1.26| 1.43|
| 300                         | (91.4)   | 1.04| 1.31| 1.48|
| 400                         | (121.7)  | 1.09| 1.36| 1.53|
| 500                         | (152.0)  | 1.13| 1.40| 1.58|
| 600                         | (182.3)  | 1.17| 1.44| 1.63|

2.3.1.4 Find V

Basic wind speed From Iraqi code by using wind map in (figure 2.2) below (المسودة الأولية لمدونة الزلزال العراقية)

### Table 2.6

| Exposure | α  | zₐ (m) | Add | Add | Add | c | l (m) | k | z₀₀₀₀ (m) |
|----------|----|--------|-----|-----|-----|---|------|---|-----------|
| B        | 7.0| 365.76 | 1/7 | 0.84| 1/4.0| 0.45| 0.30| 97.54| 1/3.0| 9.14|
| C        | 9.5| 274.32 | 1/9.5| 1.00| 1/6.5| 0.65| 0.20| 152.4| 1/5.0| 4.57|
| D        | 11.5| 213.36 | 1/11.5| 1.07| 1/9.0| 0.88| 0.15| 198.12| 1/8.0| 2.13|

Note: Wind speed zoning in IRAQ based on 3-sec Gust speed measured at 10m height in open level country with few obstructions associated with an annual probability of 0.02. The Gust speeds are modified in accordance with the recommended Gust speeds for stations in IRAQ given in Table 7 Ref. 32.

**Figure 2.2** wind speed zoning in Iraq
2.3.2 Determine the Design Wind Pressure (P) or Design Wind Load (F)
The design wind load pressure is given by following equation:-
\[ P = qz \cdot G \cdot Cp - qi \cdot (GCpi) \] (N/m²)
Where: -
- \( q = qz \) for windward walls evaluated at height \( z \) above the ground \( z \).
- \( q = qh \) for leeward walls, sidewalls, and roofs, evaluated at height \( h \).
- \( qi = qh \) for windward walls, side walls, leeward walls, and roofs of enclosed buildings and for negative internal pressure evaluation in partially enclosed
- \( G \) = gust-effect factor.
- \( Cp \) = external pressure coefficient from.
- \( (GCpi) \) = internal pressure coefficient from.

2.3.2.1 Find \( G \)
The gust-effect factor for a rigid building or other structure is permitted to be taken as 0.85.

2.3.2.2 Find \( Cp \)
\( Cp \) find from Table 2.7

| Wall Pressure Coefficients, \( Cp \) |
|------------------|------------------|------------------|
| Surface          | L/B              | \( Cp \)         | Use With |
| Windward Wall    | All values       | 0.8             | \( qz \)  |
| Leeward Wall     | 0.4             | -0.5            | \( ph \)  |
| Side Wall        | 2               | -0.3            |          |
|                  | \( \geq 4 \)     | -0.2            |          |

3. Case Studies
3.1 Introduction
Building engineered with structural walls are usually stiffer than framed structures reducing the possibility of excessive deformations and hence damage. The necessary strength to avoid structural damage under wind load can be achieved by providing a properly detailed longitudinal and transverse reinforcement. by adopting special detailing measures, depending ductile response can be achieved under major earthquakes.

Lateral forces, that is, the forces applied horizontally to a structural derived from winds or earthquakes cause shear and overturning moments in walls. the shear forces tend to tear the wall just as if you had a piece of paper attached to a frame and changed the frames shape from a rectangular to parallelogram. this changing of shape is generally referred as racking. at the ends of shear walls, there is a tendency for the wall to be lifted up at the end where the lateral force is applied.

3.2 Description of the Structure
The structures, used for the analyses, are assumed to be serving as school buildings. The detailed descriptions of the building is the follows:
Building has a regular plan (40m x 25m) as shown in Figure 3.1 each building contains 12 floors and the height of the building (42) meters The structural system is select as concrete frames with identical columns of 50/50 centimeters in size, and beams of dimension 50/30 centimeters. Each floor slab has 16 centimeters thickness and the story height is 3.5 meters.

| Hight of each storey | 3.5 m |
|---------------------|-------|
| Number of storey    | Twelve (G+11) |
| Shear wall thickness | 250 mm |
| Grade of concrete and steel | M20 and Fe 415 |
| Size of beam        | 500 x300 mm² |
| Size of column      | 500 x 500 mm² |
| location            | Baghdad |
## 3.3 – Deflection Diagram

### Table 3 – 1

| Storey Numbers | Bending moment | Shear force |
|----------------|----------------|-------------|
| Storey 12      | 14.274         | 23.483      |
| Storey 11      | 19.303         | 25.717      |
| Storey 10      | 18.873         | 25.541      |
| Storey 9       | 19.049         | 25.627      |
| Storey 8       | 19.152         | 25.697      |
| Storey 7       | 19.285         | 25.792      |
| Storey 6       | 19.449         | 25.911      |
| Storey 5       | 19.646         | 26.054      |
| Storey 4       | 19.876         | 26.219      |
| Storey 3       | 20.104         | 26.400      |
| Storey 2       | 20.393         | 26.582      |
| Storey 1       | 19.524         | 26.586      |

### Table 3 – 2

| Storey Numbers | Shear force | Bending moment |
|----------------|-------------|----------------|
| Storey 12      | 29.824      | 26.478         |
| Storey 11      | 32.221      | 33.985         |
| Storey 10      | 32.076      | 33.380         |
| Storey 9       | 31.845      | 32.835         |
| Storey 8       | 31.573      | 32.147         |
| Storey 7       | 31.239      | 31.312         |
| Storey 6       | 30.836      | 30.302         |
| Storey 5       | 30.360      | 29.112         |
| Storey 4       | 29.811      | 27.737         |
| Storey 3       | 29.181      | 26.157         |
| Storey 2       | 28.456      | 24.372         |
| Storey 1       | 27.549      | 21.913         |

### Table 3.3

| Storey Numbers | Displacement of 12 storey building without shear wall [mm] | Storey Numbers | Displacement of 12 storey building with shear wall [mm] |
|----------------|-----------------------------------------------------------|----------------|---------------------------------------------------------|
| Storey 12      | 6.428                                                     | Storey 12      | 2.183                                                   |
| Storey 11      | 6.359                                                     | Storey 11      | 2.185                                                   |
| Storey 10      | 6.204                                                     | Storey 10      | 2.143                                                   |
| Storey 9       | 5.966                                                     | Storey 9       | 2.084                                                   |
| Storey 8       | 5.647                                                     | Storey 8       | 2.002                                                   |
| Storey 7       | 5.248                                                     | Storey 7       | 1.899                                                   |
| Storey 6       | 4.768                                                     | Storey 6       | 1.776                                                   |
| Storey 5       | 4.206                                                     | Storey 5       | 1.634                                                   |
| Storey 4       | 3.571                                                     | Storey 4       | 1.471                                                   |
| Storey 3       | 2.857                                                     | Storey 3       | 1.290                                                   |
| Storey 2       | 2.074                                                     | Storey 2       | 1.078                                                   |
| Storey 1       | 1.225                                                     | Storey 1       | 0.839                                                   |
Figure 3.1 Buildings with Shear Wall (shear bending)

Figure 3.2 Buildings with Shear Wall

Figure 3.3 wind load applied to the shear wall building
3.4 – Result and Discussion

- Comparison between displacement of 12-storey building without shear wall and with shear wall at each floor level are shown in table 3.3.
- Comparison between Shear force of 12-storey building without shear wall and with shear wall at each floor level are shown in table 3.1 and table 3.2.
- Comparison between Bending moment displacement of 12-storey building without shear wall and with shear wall at each floor level are shown in table 3.1 and table 3.2.

4. Conclusion

After the results showed us, grasp the extent of the impact of the shear wall on the building, and facilitate them to resist the momentum and shear forces that come back from the impact of wind on the building. We found it important and really important to use the shear in close high buildings, particularly in areas with high winds and hurricanes, as a result of this prevents the incidence of fabric and human losses within the buildings.

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