INVESTIGATION OF THE INFILL WALL EFFECT ON THE DYNAMIC BEHAVIOUR OF RC FRAMES

M. Ömer Timurdağaoğlu¹, Ramazan Livaoğlu² and Adem Doğangün³

¹ Research Assistant, Uludag University, Bursa, Türkiye, omertao@gmail.com
² Associate Professor, Uludag University, Bursa, Türkiye, ramazanliva@gmail.com.
³ Professor, Uludag University, Bursa, Türkiye, ademdogangun@gmail.com.

ABSTRACT

The simplicity of construction and economic reasons have made the infilled frame one of the most preferred structural form for reinforced concrete (RC) frame buildings around the world. For these reasons, the usage of infill walls with reinforced concrete frames increased rapidly over the past decades. On the other hand, although the reinforced concrete frame-infill systems are commonly used throughout the world, the infill is rarely included in the numerical analysis of the structures. For this reason the main goal of this study is to investigate, obtain and compare the dynamic characteristics such as natural frequencies, mode shapes and damping ratios of RC frames with and without infill wall by using classic vibration test results within elastic limit. In addition, the contribution of infill wall to the RC frame behavior for the small strain level is also the target of this paper. For this purpose, full scaled, one bay and one storey RC frames with and without infill wall are constructed and tested.

Enhanced Frequency Domain Decomposition technique is used in order to attain the experimental dynamic characteristics of the frames. The results from tests showed that the forced vibration test measurements are sufficient and satisfying to identify the dynamic properties of the RC frames for both with and without infill walls. Furthermore, addition of infill wall to the bare frame does not have an important effect on the dynamic characteristics of the system for small strain level. On the other hand, it is shown that the application of plaster to the infill wall changes the dynamic behavior of the system significantly even for such a small forces used in this study.

Keywords: Infill Wall, Ambient Vibration, Dynamic Behavior, Modal Analysis

1. INTRODUCTION

Reinforced concrete (RC) frames with masonry infill walls are used commonly in buildings. The behavior of masonry infilled RC frames under cyclic lateral loading is very complicated because parameters affecting the behavior is quite a lot. Although it is known that infill walls enhance the stiffness and strength of the frame, the contribution of infill walls usually neglected in the structural analysis. The most important disadvantage of the infilled RC frames is the fast degradation of stiffness, strength and energy dissipation capacity under seismic loading. Hence, infill walls are considered as non-structural members and their performance to the structure is ignored. Extensive experimental [1-4] and analytical [5-9] studies have been performed in order to understand the behavior of infilled RC
frames under seismic loading. The results have shown that there is a strong interaction between the infill wall and surrounding frame for especially lateral loads from earthquakes.

However, studies about understanding the dynamic characteristics of the infilled RC frame structures are still limited. Dynamic characteristics are determined numerically and experimentally based on material properties, boundary conditions and structural properties. Numerical dynamic characteristic are usually determined by using finite element method considering appropriate material properties and boundary conditions. In this method, natural frequencies and mode shapes are obtained after performing free vibration analysis. In addition, some assumptions are accepted in the design process in the finite element analysis. For this reasons, both numerical and experimental studies should be compared for more reliable conclusions. It should not be forgotten that finite element analysis is not sufficient alone to understand the dynamic characteristics of structures because the calibration and validation process is required. Experimental methods should be used in order to verify and calibrate the analytical results.

Basically, there are two different methods to experimentally specify the dynamic properties of a structure: Classic Modal Analysis (CMA) or Forced Vibration Test (FVT) and Operational Modal Analysis (OMA) or Ambient Vibration Test (AVT). In classic modal analysis, the structure is subjected to a known input force (an impact hammer, an electro-dynamic shaker) and the reaction of the structure is measured. In the operational modal analysis, on the other hand, the system is excited by an unknown input force (wind load, ambient vibrations such as traffic load or random noise) and the response is measured. In this study, classic modal analysis is used to obtain the dynamic characteristics of infilled RC frame structures. This modal analysis type is explained below in detail. Different studies are performed on the dynamic behavior of masonry and RC structures using classic modal analysis [10-12] and operational modal analysis [13].

The classic modal analysis, within the access of the FFT (Fast Fourier Transform) spectrum analyzer in the early 1970s, has been developed up to the present. This method is based upon the measurements of FRF (Frequency Response Function) values with the help of FFT analyzer by creating vibration effects on the system. Vibration measurement and vibration test are made with modal test, modal analysis and experimental modal analysis methods. Since the aim, in the classic modal analysis, is to generate an enforcement in the system, the accelerometer, in addition to vibration analyzer, is used to create vibration such as hummer and also to record the magnitude of the enforcement. Numerical models, by using dynamic characteristics that can be measured and determined in the classic modal analysis, can be constituted which represent the behavior realistically. From this point of view, conclusions can be drawn on the performance of the structure by performing analysis [14].

In this study, two bare frames, two gas concrete and two brick infilled RC frame system are tested by using Classic Modal Analysis (CMA) to identify the effects of the material properties on the dynamic characteristics of the system such as natural frequencies, mode shapes and damping ratios. Since the strength of frame used for gas (aerated) concrete and brick infill walls are different, two different frames are tested. On the other hand, infill walls are tested with and without plaster in order to determine the effect of the plaster on the system. Enhanced Frequency Domain Decomposition technique is used in order to attain the dynamic characteristics of the frames.

2. EXPERIMENTAL PROGRAM

2.1. Prototype Structure and test specimen

A one-storey one-bay RC frame was selected as a prototype structure. The height/length (h/l) ratio for infill walls was selected to be 1/1.25. The frames were designed in accordance with the provisions of Turkish Earthquake Code (TEC). The test specimens were chosen to be 1/1 scale. The design details for the frame specimens are shown in Figure 1. The columns and beam were selected to be 0.2x0.25 m and 0.25x0.2 m respectively. Two different materials, namely gas concrete and hollow brick masonry, were selected for infill panels. For the foundation of the frame, 4x0.6x0.4 m dimensions were selected. The foundation is fixed to the ground with shear connectors.
2.2. Test setup and instrumentation

In the present study, sensitive accelerometers are used to determine the vibrations in the structure arise from environmental effects. Since the accelerometers are designed for intervals of specific sensitivity and frequency, choice of accelerometer which was used in the study was quite important. Properties of accelerometer used in this study is given in Table 1 and is depicted in Figure 2. Accelerometers are attached to the frame by drilling a hole. Quattro four channel data acquisition cell is used in the study as shown in Figure 3(a). Signals come from accelerometers and shaker transfer to this cell and then these signals were recorded and processed by SignalCalc 240 software.

In this study, classic modal analysis method is used to specify the dynamic properties of the system via measurements using a special shaker shown in Figure 3(b). 6 specimens are tested. Three of them have gas concrete infill wall (bare frame, wall without plaster and wall with plaster) and the others with hollow brick infill wall. Test specimen for gas concrete and brick masonry infilled RC frame are shown in Figure 4 and Figure 5, respectively.

| Table 1. Technical specifications of KB12VD Piezoelectric accelerometer |
|-----------------|------------------|------------------|                  |
| Sensitivity     | 10000 mV/g ± 5%  | Service temperature | -20 – 80 C        |
| Linear Frequency interval | 0.08 – 260 Hz  | Dimensions        | R=50mm H=37mm    |
| Measuring range | -0.6 - 0.6 g     | Total mass        | 150 gr           |

Figure 1. Dimensions and reinforcement details of the test specimens
Figure 2. KB12VD Piezoelectric accelerometer

Figure 3. (a) Quattro four channel data acquisition cell (b) shaker

Figure 4. Classic modal analysis tests for gas concrete frame

Figure 5. Classic modal analysis tests for brick masonry frame
2.2.1. **Material properties**

The compressive strength for the concrete used for frame both with gas concrete masonry infill wall is 20 MPa and elasticity modulus is 20,000. The compressive strength of gas concrete and brick infill wall are 1 and 4.1 MPa, respectively. On the other hand, the modulus of elasticity for gas concrete and hollow brick masonry are estimated as 800 MPa and 1000 MPa, respectively.

2.3. **Results**

In this study, six tests are conducted for two different types of frame one of which is filled gas concrete and the other is filled brick masonry. Both of these are tested under three circumstances: (1) bare frame, (2) wall without plaster and (3) wall with plaster. Consequently, six different configurations are tested and dynamic characteristics are identified using modal analysis.

Investigations are repeated separately for 0-50 Hz, 0-100 Hz and 0-200 Hz intervals either under the effects of shaker and/or environment. It is aimed to observe the noise effects that can occur at data using many different enforcement type. Data acquired from Impuls and Burst Random type enforcement is used. Results are obtained using Butterworth Band-Stop infiltration technique for 0-50 Hz interval.

At first, bare frame is tested in order to specify the effects of infill walls on the dynamic characteristics of RC frame. Later, infilled frame is tested with and without plaster. Modal analysis test results for gas concrete infilled reinforced concrete (RC) frame is given in **Figure 6**. As can be seen in this comparison two modal frequencies can be easily captured for all system. The first frequencies of the bare frame, wall without plaster and wall with plaster are measured as 18.06 Hz, 18.21 Hz and 20.61 Hz, respectively. On the other hand, second frequencies are estimated as 22.31 Hz, 22.26 Hz and 24.12 Hz, respectively. Measured frequencies for bare frame and wall without plaster are so close to each other for both measurement. Additionally, frequency of the wall with plaster is higher than the other frequencies. The reason for the frequencies of bare frame and wall without plaster are close to each other is arise from wall does not behave with together in such a small enforcement. Furthermore, dynamic characteristics does not change when adding infill wall without plaster to the bare frame under small load levels. In other words the infill wall without plaster does not compose the all system a continuum. However, when plaster is applied to the wall, a small increase is observed in frequency. This is because plaster made infill wall to behave with frame even under small load levels. Thus, the dynamic characteristic of the system changes after the application of plaster. Consequently, the response of the system to the lateral load will also change.

![Figure 6. Modal analysis results for gas concrete infilled RC frames](image)
Modal analysis test results for brick masonry infilled reinforced concrete (RC) frame is shown in Figure 7. As it is seen from the figure, the frequency obtained from bare frame and wall without plaster are very close to each other while the frequency obtained from wall with plaster is a little higher than them. As a result and similar to the comparison given above for the gas concrete infill, when the wall without plaster added to the bare frame, dynamic properties of the system does not change for small lateral load level. On the other hand, dynamic characteristics of the system varies when the plaster applied to the wall. In other words, the wall without plaster does not work with the frame under small load levels. However, the plaster, when applied to the wall, makes the wall behave together as a continuum with the frame even under small load levels. In this case, in addition to the well-known beneficial effects on seismic behaviour of the infilled frame response, the comparisons of the results showed that the plaster has an important effect on the lateral behaviour of the infilled RC frame even for small strain level. Because it may changes the dynamic properties of the system up to %14 for the first mode frequency. Thus, the total response of the system will also change.

![Figure 7. Modal analysis results for brick masonry infilled RC frames](image)

3. CONCLUSIONS

In this study, two bare frames, two gas concrete and two brick infilled RC frame systems are tested using classic modal analysis (CMA) to identify the effects of the material properties on the dynamic characteristics of the system. In these tests, the effect of infill walls on the dynamic behavior of the RC frames is investigated.

In conclusion, from the modal analysis tests, it is seen that the infill wall without plaster does not have an influence on the dynamic properties of the RC frame for small strain level. However, on the other side, dynamic characteristics of the RC frame may change significantly when the plaster applied to the wall even for small strain level. In other words, the plaster has an important effect on the dynamic behavior of RC frame. This makes the wall frame system a continuum and behave simultaneously. In other word, in presence of the infilled wall for frame may not change the response at the beginning of applications of lateral load, after certain load level the wall will begin to contribute to frame lateral load capacity. However increasing the frequency of the system the plaster may have considerable contribution of lateral load capacity of the system even for so small lateral loads.
REFERENCES


