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MEASUREMENT OF RESIDUAL DEFORMATION OF A STRUCTURE USING MEMS ACCELEROMETER

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Abstract: *Residual deformation of a structure after a seismic/wind event plays a vital role in evaluating the structure's performance and its economic consequences. Nevertheless, studies on the measurement of residual deformation have been less emphasized. Thus, the past study evaluated the deformation of a reinforced concrete cantilever wall using MEMS accelerometers continuously attached at multiple points and verified that multiple point measurement improved the accuracy of deformation measurement, especially in low deformation by comparing the results from displacement transducers. The accuracy was significantly higher than measurement by a general-purpose inclinometer. However, the method is difficult to implement on an actual structure since continuous attachment of accelerometers requires a regular power supply, space, and affects the structure's aesthetics. Hence, the objective of this study is to measure the residual deformation of an actual structure by attaching the accelerometer only at the time of measurement. To achieve the objective, multiple point measurement was performed on a 9-story reinforced concrete school building in Japan, using an accelerometer compatible with measuring acceleration in three directions simultaneously. Periodic measurements were performed by attaching and detaching an accelerometer for 3 months during which no major events were recorded, and the inter-story drift over time of the second story was evaluated. The value of inter-story drift over time was negligible which was concurrent with the fact that there was no possibility of story deformation, confirming the applicability of the residual deformation measurement of a real structure using MEMS accelerometer. The method is characterized by its cost-effectiveness, ease, and swift implementation, along with its high accuracy. Hence, this study contributes to emergency risk assessment and the safety of a structure.*

1. Introduction

During seismic/wind events, lateral loads act on a structure, consequently, structural components or the structure as a whole deform to dissipate energy. If the structure is sound enough compared to the applied forces, it would respond elastically without any residual deformation. However, reports from past earthquake reconnaissance and results from analytical studies revealed that most engineered structures will undergo residual deformations in the event of a design-level earthquake, even if they perform exactly as expected (Christopoulos et al. 2003). This is due to the fact that for economic reasons, structures are designed to respond inelastically during infrequent severe events; thus, sustaining the residual damages. The level of those residual damages in terms of crack width/residual deformation etc. plays a vital role in estimating the residual capacity of the structure to ensure the safety of the occupants during possible future seismic/wind events.

Right after seismic/wind events, emergency risk assessment of the structures in the affected area is crucial to prevent the consequences due to aftershocks for life safety and to judge the functionality of the structure. The decision of risk assessment based on the visual inspections may vary according to the experience of the investigator and is sometimes difficult to conduct since most of the structural members are covered by finishing (Kusunoki (2021)). In such cases, when there is no visible damage on the structure that makes the visual inspections difficult, residual deformation is an appropriate way to investigate the performance of the structure during future events and the economic consequences. Moreover, even if the damages/cracks are visible, it is difficult to distinguish whether they are the result of the event or due to other factors such as shrinkage of concrete, temperature changes, inadequate curing etc. making the risk assessment more challenging. For this, some methods associated with residual deformations for instance FEMA (2012) provides specifications to investigate the building damage stages based on the residual inter-story drift. Moreover, a past study by McCormick et al. (2008) based on the extensive literature review suggested 0.005 rad as an index level for the permissible residual deformation. However, studies on residual deformation measurement have received less attention. The more severe the seismic/wind event, the larger the damaged structures that have to be investigated, demanding a great deal of time, effort, and financial resources. As a result, sensor-based structural health monitoring system has gained popularity(Paek et al. (2005); Petrone et al. (2018); Ferreira et al. (2022)) since it is expected that this reduces the required time and labour. Thus, occupants can confirm the safety or arrange for evacuation if the structure is not safe immediately after the event. However, some of the problems associated with the existing monitoring system include high cost, requiring expertise for data analysis, difficulty in installation and demand for space for the installation affecting the aesthetic of the structure.

To resolve the difficulties mentioned above, the authors have been investigating structural health monitoring by using inexpensive Micro-Electro-Mechanical System (MEMS) based sensors (MEMS sensor) (Hara et al. (2022), Pradhan et al. (2023), Sata et al. (2023)). In authors' previous study, the deformation of a reinforced concrete (RC) cantilever wall was evaluated by continuously attaching MEMS accelerometers at multiple points and verified the evaluated deformation by comparing the deformation from displacement transducers. However, the method required continuous attachment of sensors demanding regular power supply, and space affecting the structure's appearance. Thus, to overcome such drawbacks, this study proposes a new method to evaluate the residual deformation of structure/building by attaching the MEMS accelerometer only at the time of measurement. This study 1) summarizes the previous study verifying the deformation evaluation method of RC cantilever wall by continuously attaching MEMS accelerometer at multiple points (Pradhan et al. (2023), Sata et al. (2023)), 2) explains and verifies the residual deformation/drift evaluation method of actual building by attaching MEMS accelerometers at multiple points only at the time of measurement. The proposed method consists of monitoring the structure before and after the event to evaluate the residual deformation caused by the event. It was concluded that the proposed method can be effectively used to evaluate the residual deformation/drift of earthquake/wind damage structures with less effort. Thus, this study contributes to the emergency risk assessment of structures immediately after seismic/wind events for the safety of the occupants.

2. Summary of Previous Study

To propose and verify the deformation evaluation method by using the MEMS accelerometer, two identical RC cantilever walls were prepared, which were loaded with static cyclic and dynamic loads (Pradhan et al. (2023), Sata et al. (2023)). This study, however, summarizes only the static cyclic loading test. Figure 1 shows the test setup with the detail of instrumentation in the previous study. To monitor the displacement/deformation, 2 displacement transducers (LVDT) at the centre of the stub and 2 at the top of the specimen were fixed, whereas 10 MEMS accelerometers were affixed on the specimen at different heights as shown in Figure 1. The data sampling rate of the MEMS accelerometer was 120 Hz. The specimen's stub was attached to the actuator, whereas the top of the specimen was attached to the reaction frame (Figure 1). Displacement control static cyclic loads were applied based on the loading history as shown in Figure 2. Horizontal loads were applied to the specimen by moving the actuator slowly forward and backwards while keeping the top of the specimen fixed to the reaction frame. The deformation of the specimen was evaluated assuming a deflection curve of cubic function (detail is explained in Section 4) using the collected data from the MEMS accelerometer and compared with the deformation from the LVDT. Figure 3 compares the deformation of the specimen from the MEMS accelerometer and the LVDT during the last three loading cycles. The comparison shows that the evaluated deformation using the MEMS accelerometer had very good agreement with that from LVDT particularly in low deformation. Thus, this reveals that the multiple points measurement with the MEMS accelerometer improved the accuracy of deformation measurement, especially in low deformation. Hence, the same deformation evaluation method using a MEMS accelerometer was applied in this study to evaluate the residual deformation/drift of an RC building.

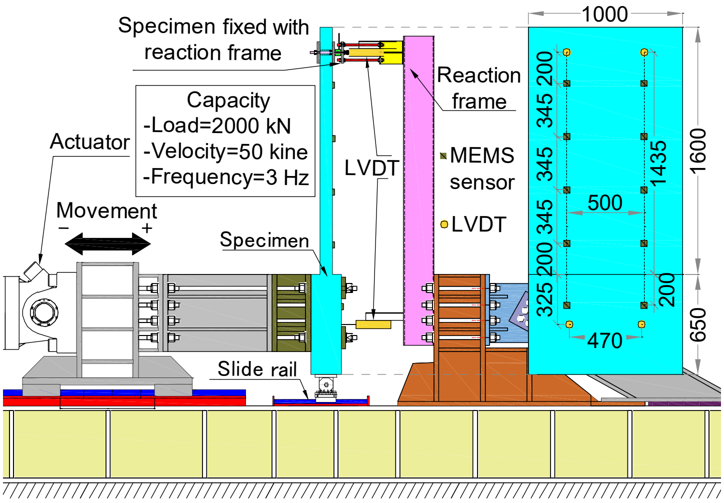


Figure 1. Test setup in previous study. (Unit: mm)

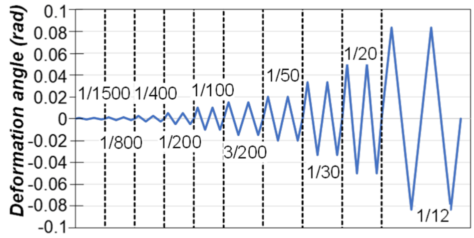


Figure 2. Loading history.

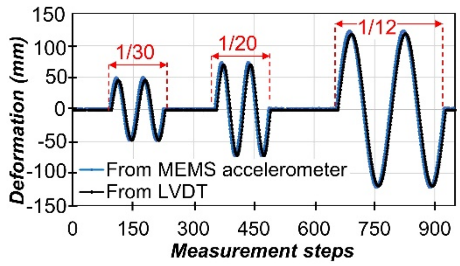


Figure 3. Comparison of deformation.

3. Study Building and Instrumentation

The study building in this study is a 9-story superstructure including one underground story RC school building in Japan. Figures 4 and 5 show the Northeast view and the first-floor plan of the building which is common among all the floors. Measurements were performed using a MEMS accelerometer on the first and second floor columns. Deformation of the columns on the East and West sides was monitored for both the first and second stories, whereas columns on the North and South sides were monitored only for the first floor. To maintain the tidiness of the measurement area, first fabric tape was affixed on the column then a steel plate was attached over the fabric tape using adhesive as shown in Figure 6. As shown in the figure, a MEMS accelerometer measurement unit was prepared by fixing the accelerometer on the steel plate with a magnet on the opposite side. In order to ensure consistency of the measurement location/position and ease of detaching and attaching the measurement unit with precise position, identical steel plates of size 50 x 50 mm were used for the entire measurement. The total story/column height is 3.65 m. Measurements were performed at three different heights at 0.4 m (S1), 1.2 m(S2), and 2.0 m(S3) of each story/column as shown in Figure 7. Hence, measurements were performed on a total of 18 points (6 columns @3 points on each column). The measurement unit was fixed over a steel plate on the column and the measurement was performed, then the

Figure 4. Northeast view of study building.

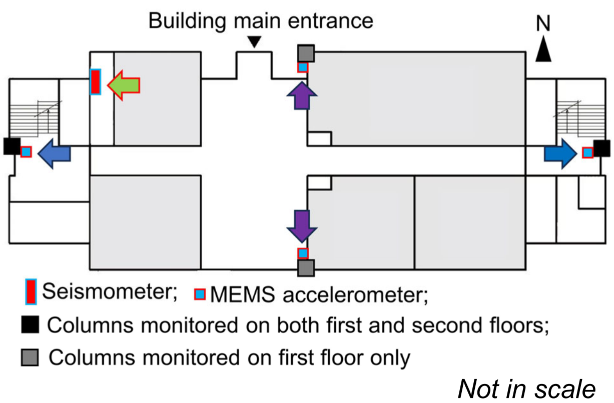


Figure 5. First-floor plan of study building with instrumentation location.

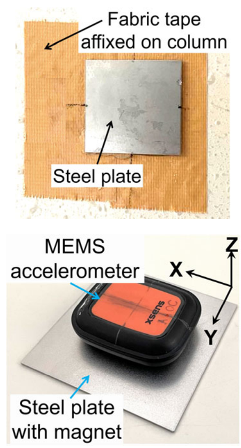


Figure 6. Measurement setup.

unit was moved to the next measurement point and the measurement was conducted in a similar manner. The same measurement unit was used for the equipment consistency during the entire monitoring period. Periodic monitoring/measurement was conducted from 21st April 2023 to 26th June 2023 and data were collected when there was minimum disturbance to collect real data only concerned with the column deformation. Moreover, to track tremors on the building due to any event that may affect the column deformation, a seismometer was installed on the first floor as shown in Figure 5. The seismometer is compatible with recording vibration/accelerations in all three axes (2 horizontal and 1 vertical axis) simultaneously. After the monitoring period, the measurement related setup was removed, and it was confirmed that no scar/mark was left on the column revealing that the adoption of the proposed method can preserve the original appearance of the structure.

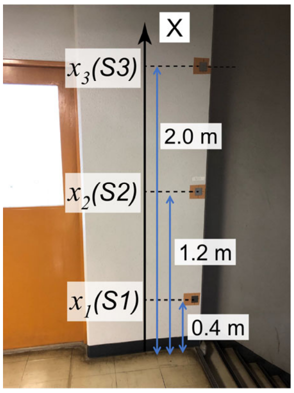


Figure 7. Measurement points on column.

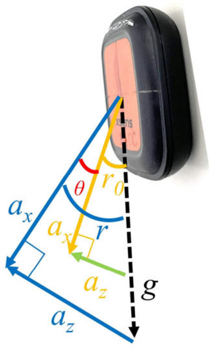


Figure 8. Tilt and rotation angle.

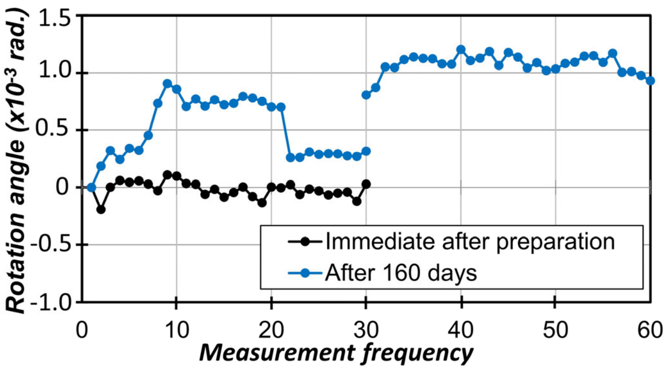


Figure 9. Effects of attaching and detaching the measurement unit on rotation angle of measurement unit.

4. Residual Deformation Evaluation

4.1 Rotation angle using MEMS accelerometer

The same MEMS accelerometer was used in the previous study (Pradhan et al. (2023), Sata et al. (2023)) and the current study as shown in Figure 6. The MEMS accelerometer was Xsens dot for motion capture (acceleration range ±16G, internal sampling frequency 1Hz～120Hz, rechargeable battery, weight 11.2 grams, dimensions 36.3 x 30.4 x 10.8 mm, wireless communication). The accelerometer is compatible to measure acceleration as well as angular velocity in all three axes (X, Y, Z in Figure 6) simultaneously. However, in this study, only the acceleration values were used for the detailed study. The data sampling rate was 60 Hz.

Figure 8 shows the tilt angle (r) and rotation angle (θ) of the MEMS accelerometer measurement unit attached on the structure/column in the direction perpendicular to the attached surface, which can be assessed from Equation (1) as a change in the direction of gravitational acceleration using the measured accelerations in X and Z axes. In this study, the measurement unit was attached to the columns as shown in Figure 7 and its position was arranged such that the tilt angle (r) would be positive if the column deformed in the building's outer direction (columns DE, EF in Figure 12). The preliminary tilt angle (r) of the structure before any damage or any event is regarded as the initial tilt angle (r_0) that represents the original state of the structure/column. This study suggests monitoring the tilt angle (r) periodically or whenever necessary for the health monitoring of the structure. Then the rotation angle (θ) of the column at the accelerometer installation point at any instant can be evaluated as a change in tilt angle (r) with respect to the initial tilt angle (r_0) as shown in Equation (2). Hence, even if a structure has some initial deformation/inclination due to the possible construction toleration, this study assumes it as zero since the evaluation of residual deformation/drift of a structure absolutely due to an event is the main target of the study.

$$r = tan^{-1}\frac{a_z}{a_x} \cong \frac{a_z}{a_x} \quad (1)$$

$$\theta = r - r_0 \quad (2)$$

where,

a_x, a_z = Measured accelerations in the X and Z axes respectively

r= Tilt angle of the MEMS accelerometer measurement unit at any instant of time

r_0= Initial tilt angle of the MEMS accelerometer measurement unit

θ = Rotation angle of the MEMS accelerometer measurement unit

The MEMS accelerometer was very sensitive as a result it can detect trivial changes in the acceleration; thus, there were variations in the collected acceleration data even when the accelerometer was kept stationary. Hence, an average value of measured acceleration over a certain timespan was planned to use to evaluate the tilt angle (r) to reduce noise and thereby ultimately improve the accuracy. The accuracy of the evaluated results also depends on the timespan considered for the average acceleration evaluation. For the rapid risk assessment, the timespan should be as short as possible with a sufficient degree of precision. Hence, to decide the appropriate timespan, acceleration data was collected by fixing the MEMS measurement unit on a column and the tilt angle (r) was evaluated for different timespans. Table 1 shows the standard deviation of the tilt angle (r) for different timespans. It shows that the standard deviation was negligible for any timespan; however, in this study, the timespan was taken as 30 seconds since this is neither too long nor too short and appropriate for the rapid risk assessment.

Table 1. Measurement timespan and precision of tilt angle

Time span (s)	10	20	30	40	50	60
Numbers of data	600	1200	1800	2400	3000	3600
Average value of tilt angle (x 10^{-2}rad.)	1.15	1.15	1.15	1.14	1.14	1.14
Standard deviation (x 10^{-4})	7.36	7.38	7.35	7.36	7.40	7.41

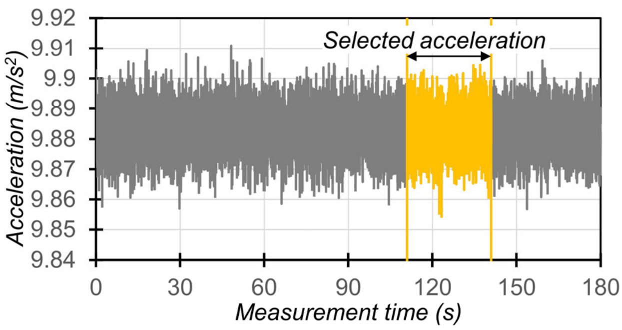
4.2 Effects of attachment and detachment of measurement unit

This study proposes an innovative approach to evaluate the residual deformation of a structure due to an event by monitoring the deformation/tilt angle (r) before and after the event. Moreover, to verify the proposed method, this study comprises periodic deformation evaluation by attaching and detaching the MEMS measurement unit which may cause a sampling error. Hence, in order to quantitatively investigate the effect of such sampling errors on the rotation angle (θ), an additional test was performed by attaching and detaching the measurement unit several times. The rotation angle (θ) was evaluated using the same procedure and sampling timespan as explained in Section 4.1. Figure 9 shows the relation between the measurement frequency and the respective rotation angle (θ). In the figure, the black line represents the test results of attaching and detaching the unit 30 times, performed immediately after the preparation of the measurement setup (Figure 6). Whereas blue lines represent the test results for two measurement steps (first step, measurement frequency 1-30 and the second step, measurement frequency 31-60) which were performed 160 days after the measurement start date. Each measurement step included 30 times attaching and detaching the unit, the interval of the measurement steps was 2 hours. For both measurement steps, the initial tilt angle (r_0) was considered as the tilt angle measured at the beginning of the day.

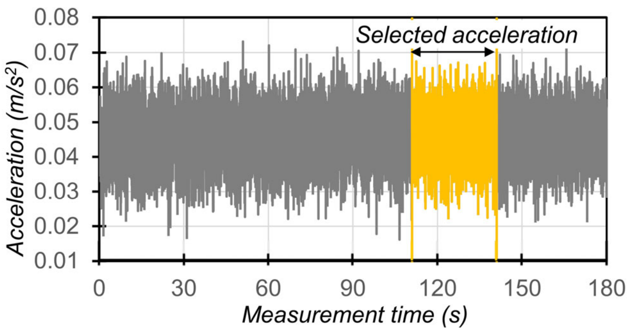
The results immediately after the preparation of the measurement setup (black line in Figure 9) showed almost no effect of attachment and detachment of the measurement unit on the rotation angle (θ). However, during both measurement steps (1-60 measurement frequency) on the 160th day, the rotation angles (θ) were positive i.e. the tendency of the measurement unit to lean backwards was observed showing the maximum error of $1.2x10^{-3}$ rad which is considered negligible. The phenomenon behind such an error is considered due to the deterioration of the fabric tape affixed on the column (for the tidiness as explained in Section 3) within 160 days of the preparation start date. This investigation revealed that the effect of attachment and detachment of the measurement unit have a limited effect on the rotation angle (θ); thus, it was concluded that the method can be used effectively to evaluate the residual deformation of the structure.

4.3 Acceleration data based on MEMS accelerometer

The MEMS measurement unit was installed at three different heights of a column as explained in Section 3. The sampling data was collected for approximately 180 seconds for each measurement point, which is equivalent to 6 times the timespan (30 seconds) used to evaluate the average values. Figure 10 shows the time history of measured raw data along with the selected acceleration data (30 seconds) that produced a relatively steady tilt angle (r) i.e., minimum standard deviation tilt angle for further evaluation.



a) X-axis acceleration



b) Z-axis acceleration

Figure 10. Time history of acceleration data from original measurement (Fist floor, west, S1).

4.4 Evaluation of residual deformation/drift

The deformation of columns was evaluated using the rotation angle (θ) of the MEMS measurement unit affixed on the columns at different heights. From the fundamental principle of mechanics, the curvature (φ) is defined as the reciprocal of the radius of curvature (ρ) and is given as the second derivative of the deflection (y) as illustrated in Equation (3) (Beer et al. (2015)). From the flexural equation, bending moment (M) acting on a member can be assumed proportional to the curvature (φ); thus Equation (3) can be modified as Equation (4).

$$\varphi = \frac{1}{\rho} = \frac{d^2y}{dx^2} \tag{3}$$

$$\frac{d^2y}{dx^2} = \frac{M}{EI} \tag{4}$$

Assuming constant shear force (Q) on the column on each story, the rate of change of the bending moment (M) will be constant as indicated in Equation (5). Then Equations (4) and (5) imply Equation (6) revealing that the deflection curve of a member can be expressed as a cubic curve i.e., $y = f(x)$ as shown in Figure 11. The deflection/deformation curve of the column passages through the column base as indicated by point O in Figure 11. Assuming the column base as an origin (x=0 and y=0 in Equation (6)) this implies d=0 in Equation 6. The slope of the column at any point is equivalent to the rotation angle (θ) of the MEMS measurement unit at the respective point and can be evaluated as the first derivative of the deflection/deformation equation (Equation (6)) as shown in Equation (7).

$$\frac{dM}{dx} = constant \tag{5}$$

$$y = f(x) = ax^3 + bx^2 + cx + d \tag{6}$$

$$dy/dx = f'(x) = \theta = 3ax^2 + 2bx + c \tag{7}$$

Assigning the value of rotation angle (θ_1 to θ_3) measured by the MEMS accelerometer at different heights (x_1 to x_3) of the column in Equation (7) gives the matrix form as shown in Equation (8).

$$\begin{bmatrix} 3x_1^2 & 2x_1 & 1 \\ 3x_2^2 & 2x_2 & 1 \\ 3x_3^2 & 2x_3 & 1 \end{bmatrix} \begin{bmatrix} a \\ b \\ c \end{bmatrix} = \begin{bmatrix} \theta_1 \\ \theta_2 \\ \theta_3 \end{bmatrix} \quad (8)$$

where,

x_1 , x_2 , x_3 = Height of MEMS accelerometer from the floor, in this study, x_1 =0.4 m, x_2 =1.2 m and x_3 = 2.0 m

$\theta_1, \theta_2, \theta_3$ = Rotation angle of the MEMS accelerometer measured by accelerometers S1, S2, and S3 at height x_1 , x_2 , x_3 , respectively (Figure 7).

Equation (8) gives the solution for a, b and c. Then the column deformation can be evaluated using Equation (6) with x = column height (H). Assuming a rigid building floor, the residual story drift and inter-story drift as shown in Figure 12 can be evaluated using Equations (9) and (10) respectively.

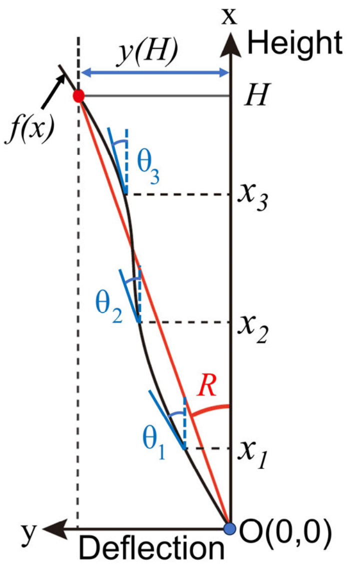


Figure 11. Deflection curve.

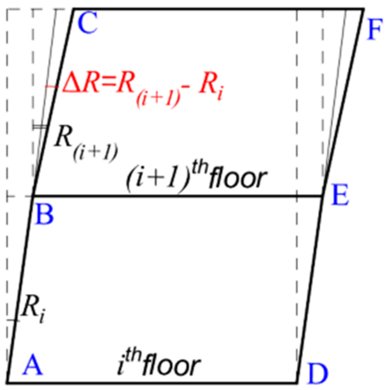


Figure 12. story and Inter-story drifts.

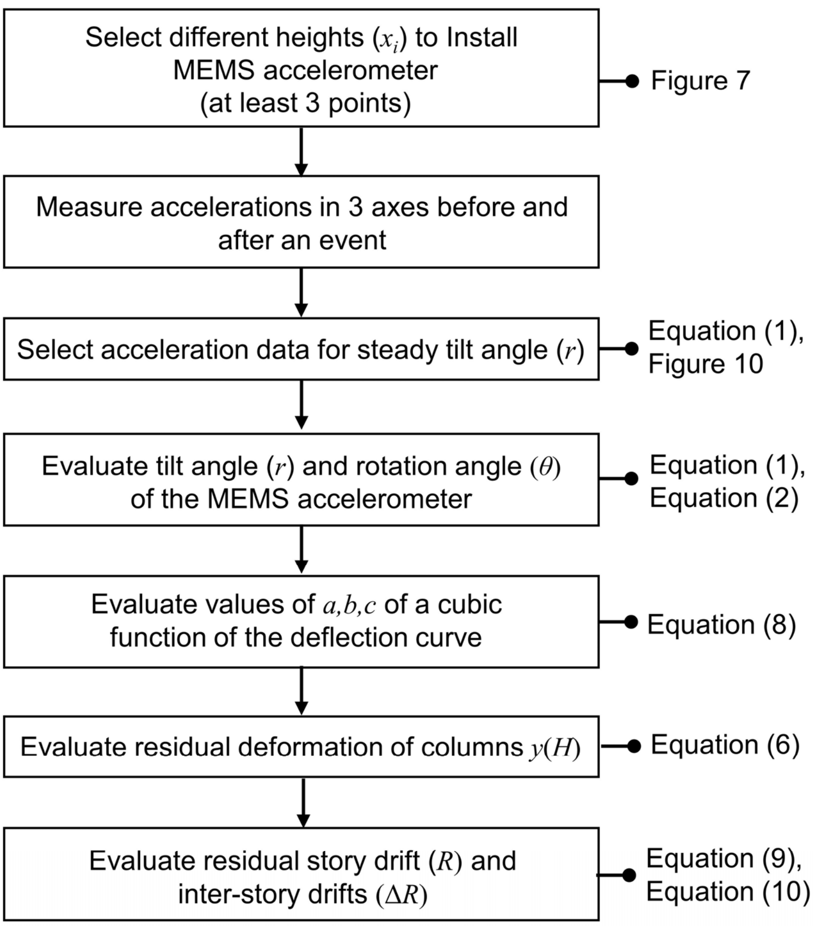


Figure 13. Overall flow to evaluate residual deformation using MEMS accelerometer.

$$R = \frac{y(H)}{H} \quad (9)$$

$$\Delta R = R_{(i+1)} - R_i \quad (10)$$

where,

$y(H)$ = Deformation of the column at the top

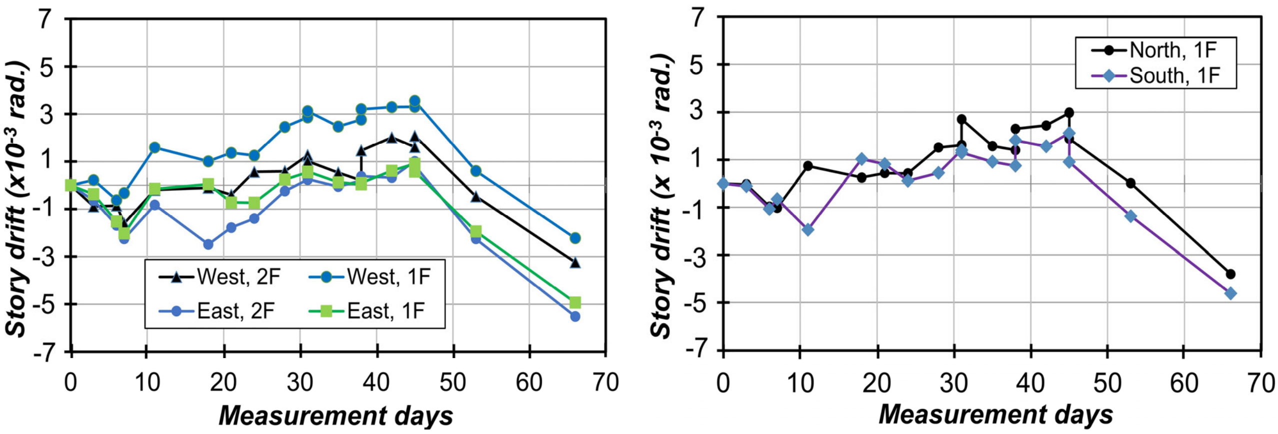
H = Height of column (=3.65 m)

R= Story drift

R_i, R_{i+1}= Story drift of *i*th and *(i+1)*th floor, respectively

ΔR= Inter-story drift

Figure 13 summarizes the overall flow to evaluate the residual deformation of a structure based on the proposed method in this study using a MEMS accelerometer. Figures 14, and 15 show the evaluated residual drift of columns on both the first and second story and the inter-story drift of the second story in East-West directions evaluated following the procedures as summarized in Figure 13.



a) East and West side columns *b) North and South side columns*

Figure 14. Residual story drifts from each column.

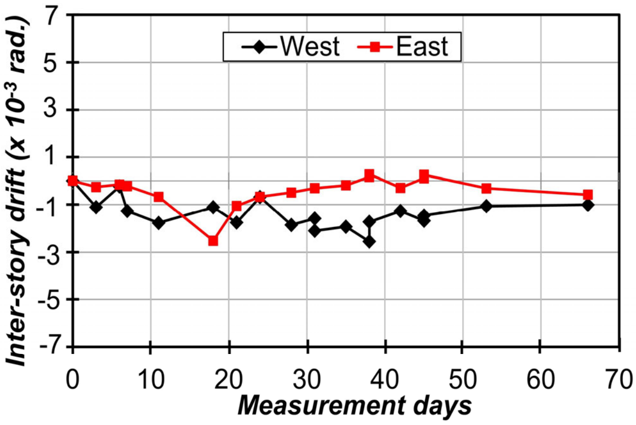


Figure 15. Residual inter-story drift of second story.

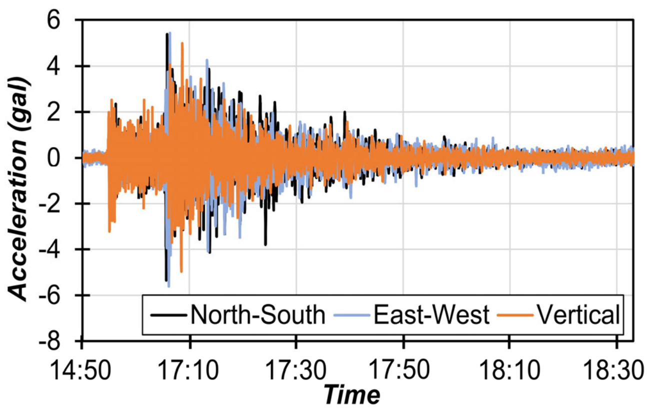
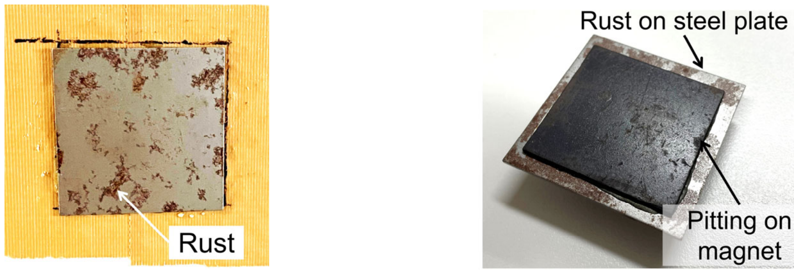


Figure 16. Maximum tremor on the study building recorded by seismometer on 2023/5/11.

5. Verification of Proposed Residual Deformation Evaluation Method

Figure 16 shows the maximum vibrations/tremors on the building during the measurement period (from 21st April 2023 to 26th June 2023) recorded by the seismometer installed on the first floor as explained in Section 3 (Figure 5) on 11th May 2023. The maximum recorded accelerations were 5.4 gal, 5.6 gal and 5.0 gal, in North-South, East-West and Vertical directions respectively. This revealed that no stronger tremor was observed on the building during the monitoring period which is likely to cause the building/column to deform. As shown in Figure 14, approximately up to 7 days most of the columns on all sides of the building have negative drift, which represents columns deformed inwards the building like columns AB, and BC in Figure 12, then up to 45 days columns have positive drift representing columns deformed outwards the building like columns DE, EF in Figure 12 and again deformed inwards. This indicates that during the monitoring period, the floor slab bulged, sank, and then bulged again, which is not a possible phenomenon for the study building. Hence, the evaluated deformation is assumed primarily due to the changes on the steel plate and magnet over time caused by rusting and pitting which was observed at the end of the monitoring period as shown in Figure 17. Moreover, another cause might be due to the error on the MEMS accelerometer over time. However, the maximum alteration on the evaluated residual drift was only 5.5×10^{-3} rad on the East side column of the second story, which is very small. Figure 15 shows the evaluated residual inter-story drift of the second story, which shows negligible variation over time (maximum inter-story drift was 2.2×10^{-3} rad) which is considered due to defects on the steel plates, magnet and MEMS accelerometer as explained. The evaluated story drift and inter-story drifts were negligible which is equivalent to no residential deformation on the study building. Consequently, this reveals that the evaluated residual deformation (no residual story and inter-story drift) of the study building based on the proposed method is congruent with the fact that there was no possibility of having a residual deformation on the building as explained. Hence, this confirms that the proposed method is reliable and appropriate for the rapid safety assessment of structures after seismic/wind events.



a) Steel plate affixed on columns b) Magnet affixed on MEMS accelerometer

Figure 17. Observed changes on measurement accessories over time.

6. Discussion

This study proposed and verified a simple residual deformation/drift evaluation method of a structure using a MEMS accelerometer. The proposed method assumed the deformation behavior of a member as a cubic curve based on the flexural equations and fundamental principles of mechanics. The method also assumes the constant flexural stiffness (IE) of the member (i.e. IE is the same before and after the event) i.e. the method assumes the plane section of the member remains plane even after bending (I remains constant) and the constant flexural modulus (E remains constant). Thus, the proposed method mainly targets columns and beams, where flexural deformation is dominant, and the cross-section is uniform throughout its length. In contrast, the method is not appropriate for members that undergo large shear deformation, such as walls and for the members that have varied cross-sections along their length or when the member's cross-section cannot be regarded as uniform because of the damage, etc. The method assumes the continuous flexural deformation cubic curve; thus, to apply the proposed method, at least 3 points of a member should be monitored. Thus, if severe crack/damage occurred between the monitored points (between S1 to S3 in Figure 7) of the member, the approximation by the proposed method would not be reliable. To verify the proposed method, the method was applied to an RC school building in Japan. The evaluated story/inter-story drift of the building has a negligible error, which is assumed mainly due to the rusting of the steel plates and pitting on the magnet used for the measurement. Had the plates and magnet been protected using a protective coating, the error would have been more minimal. Considering such factors, it can be said that the evaluated story/inter-story deformation of the building based on the proposed method was zero, which is consistence with the fact that there was no possibility of having a residual deformation on the building since no major event was encountered causing the building/column to deform. Hence, this study verified that the proposed method is appropriate to evaluate the residual deformation of the structure. Moreover, the method is easy to apply, relatively cheap with less time for implementation and maintains the tidiness and appearance of the structure. Hence, this study recommends applying the proposed method for rapid post-seismic/wind event safety assessment to estimate the performance during aftershocks, primarily for public buildings for instance hospitals, school buildings, public libraries etc. which are supposed to be used as evacuation shelters.

7. Conclusions

This study proposed an innovative approach to evaluating the residual deformation of a structure caused by earthquake/wind loads using a MEMS accelerometer by attaching the accelerometer only at the time of measurement. The proposed method was applied to an RC building in Japan and verified the applicability of the proposed method. The major findings of the study are summarized below.

1. The proposed method comprises attaching and detaching the accelerometer on the monitoring surface. Hence, the effect of attachment and detachment of the accelerometer on the accelerometer rotation angle was investigated and it was confirmed that the effect is very small and limited only to $1.2x10^{-3}$ rad.
2. The proposed method assumes deformation behavior as a cubic curve and constant flexural stiffness of the member. Hence, the proposed method is not appropriate for members that undergo large shear deformation and for members with varying cross-sections along their length.
3. Residual story drift and the inter-story drift of an RC building were evaluated using the proposed method in this study. The evaluated residual story/inter-story drift of the building was negligible (with limited error of $2.2\ x10^{-3}$ rad in inter-story drift) due to some error, which was caused by factors that can be controlled easily. Hence, the evaluated residual story/inter-story drift of the building can be considered zero, which satisfies the fact that there was no possibility of having residual deformation since no event occurred during the monitoring period. This confirms the applicability of the proposed method with high precision to evaluate the residual deformation of the structure.
4. After the monitoring period, the measurement arrangements were removed and confirmed that the application of the proposed measurement method in the study has no effect on the appearance and maintains the tidiness of the structure. The proposed method is characterized by its cost-effectiveness, ease, and swift implementation, along with its high accuracy. Hence, this study contributes to emergency risk assessment and the safety of a structure. Along with being high level of precision, the proposed method is cost-effective, simple to apply, and requires less time to implement. So, this study suggests applying the method for the prompt post-seismic/wind event safety assessment of structure.

This study proposed and verified an innovative method to evaluate the residual deformation/drift of a structure using a MEMS accelerometer and contributes to emergency risk assessment and the safety of a structure. Investigation of performance of a structure during seismic/wind events is also a crucial factor in the health monitoring of a structure. Hence, the authors will continue to propose a new approach to investigate the performance of structure during seismic/wind events using sensors.

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