Table 4 Possibility of damage related to Ranau seismic intensity, VIII

Damage distribution possibility for different Seismic Intensity in %		
Mean damage grade	**Description**	**Seismic Intensity I_{EMS} VIII**
D2	Slight SD, Moderate N-SD	33.1
D3	Moderate SD, Heavy N-SD	28.8

Based on the vulnerability results presented in Fig. 6, Fig. 7, and Table 4 the seismic event with intensity VIII of 0.702 average vulnerability index, results in structural mean damage grades of 33.1% and 28.8% between D2 and D3, respectively, meaning that the vulnerability of the non-structural elements in the building suffered from moderate to heavy damages. Thus, the result is very compatible with the field observations after Ranau earthquake in Sabah-Malaysia. Moreover, it was observed from the analysis outcome that the formation of plastic hinges was significantly concentrated in the bottom and 1st floors RC-column which have experienced high interstorey drift ratios due to weak column-strong beam design approach, as shown in Fig. 8(a) and (b).

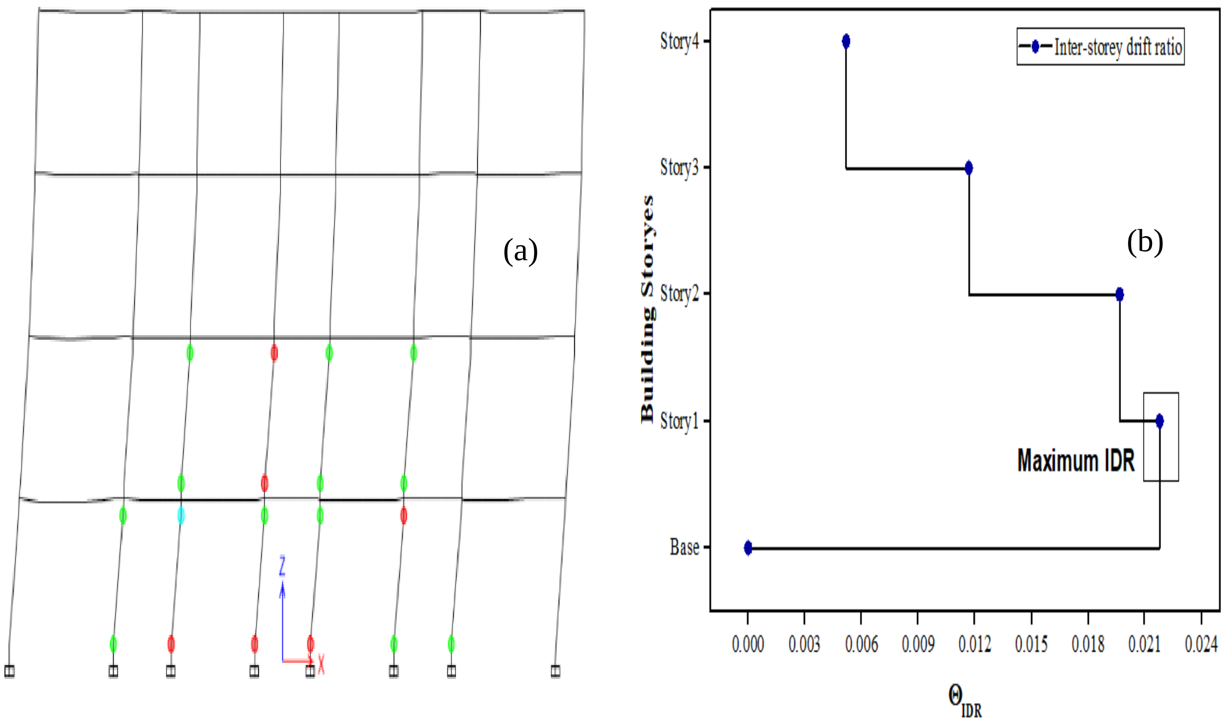


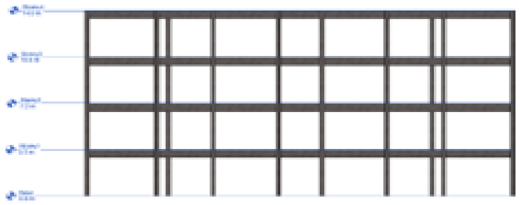
Fig. 8 SMK-School building damages represented by (a) fragility curves (b) probability of mean seismic vulnerability index for grades D2 and D3.

4.4. SEISMIC VULNERABILITY IND

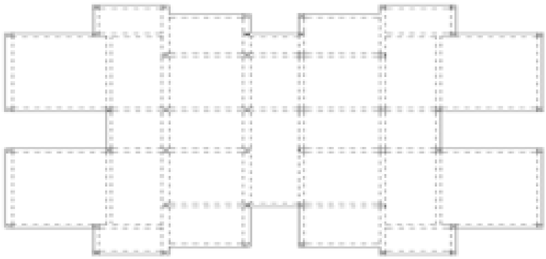
Seismic Vulnerability Index of SMK-School Building in Sabah-Ranau
Data Collection Form

Surveyor Name(s):
Date:

Elevation View



Plan View



Address: Sabah-Ranau

Building Name: Sekolah Menengah Kebangsaan (SMK)

Number of Storeys: Four Storeys

Story Height(m): 3.5metre

Total Floor Area(sq-m): 1899 sq-metre

GPS Coordinate (If available): (5°58'29.1"N 116°40'24.9"E)

Construction Drawing Available: Yes ☒ / No☐

Occupancy Type

☐Assembly ☐Government ☐Office ☐Commercial
☐Historic ☐Residential ☐Industrial ☒School

Soil Type (NEHRP 2000)

☐A (Rock) ☐B (Rock) ☐C (Soft Rock)
☒D (Stiff Soil) ☐E (Soft Soil)

Seismic Vulnerability Index Score (VI)

Number	Parameters	Vulnerability Classes Weighing Parameters (Kn)			SVI, Mean
		Low (L)	Moderate (M)	High (H)	
1	Beam-Column Connection Joint	0.127	0.076	0.060	$SVI_{mean}=\sum Kn = 0.702$
2	Boundary Condition Support	0.127	0.077	0.059	
3	Diaphragm Floor System	0.128	0.0076	0.059	
4	Type of Soil	0.115	0.087	0.061	
5	Building Ductility	0.164	0.059	0.041	
6-7	Mass Irregularity (V and H)	0.112	0.086	0.065	
8	Concrete Strength	0.114	0.083	0.067	
Total Seismic Vulnerability Index (L, M, and H) ERDs		1	0.630	0.477	0.702

Result Interpretation:

Modelling and Design classes according to vulnerability:
Low Class (L): The parameter is not designed within seismic regulations and away from consistency, where the performance is in low resisting to seismic loading.
Moderate Class (M): The parameter is in moderate performance to resist seismic loading, intermediate position.
High Class (H): The parameter is specially designed according to seismic code, and in high performance to resist seismic loading

RC-building Vulnerability Classifications:
Green 1: 0.1<VI<0.2, VI_{Mean} = 0.15
Green 2: 0.2<VI<0.4, VI_{Mean} = 0.3
Orange 3: 0.4<VI<0.55, VI_{Mean} = 0.475
Orange 4: 0.55<VI<0.7, VI_{Mean} = 0.625
Red 5: 0.7<VI<1, VI_{Mean} = 0.85

Damage Categories	Class	Description
Negligible	Green 1	Negligible to light damage
Minor	Green 2	Light for the structural elements, and moderate for the not structured elements
Moderate	Orange 3	Moderate for the structural elements, and heavy for the not structured elements
Serious	Orange 4	Heavy for the structural elements, and heavy for the not structured elements
Collapse	Red 5	Collapse Total or close

Further Evaluation Recommended

Yes ☒ No ☐

5. CONCLUSION

The vulnerability assessment of a reinforced concrete school building was conducted using an improved seismic vulnerability index via nonlinear parametric analysis. The proposed methodology and its application are validated by obtaining a good correlation between the analytical results and the observed fragility features in the field investigations. According to the obtained probabilistic vulnerability curves for different seismic scenarios, the reference building is classified to be in D2 and D3 damage grades, which is thoroughly correlated to the observed damage in the field in-situ investigations during Ranau earthquake of seismic intensity (VIII).

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