# VULNERABILITY REDUCTION SOLUTIONS

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|---|---|
| Date: | 03/10/2018 |
| VRS Code: | FRS |
| Author: | UCL |
| Sheet: | 1 OF 2 |

**LOAD BEARING MASONRY BUILDINGS**

**STRENGTHENING INTERVENTION:** **ROOF STRENGTHENING**

**APPLICABLE BUILDING TYPES:**

| | Taxonomy Parameters | | | | |
|---|---|---|---|---|---|
| Main Structural System:…… | A [X] | UCM-URM [X] | CM [X] | RM [X] | SFM [X] |
| Height Range:…… | | Low (LR) [X] | | Medium (MR) [X] | High (HR) [X] |
| Seismic Design Level:…… | Poor (PD) [X] | Low (LD) [X] | | Medium (MD) [X] | High (HD) [ ] |
| Diaphragm Type…… | | | | Flexible [X] | Rigid [ ] |

**EXISTING STRUCTURAL DEFICIENCIES:**

-Timber or Steel roof structure with rafters and purlins only (no diagonal bracing); - Poorly connected joints; - Limited in-plane strength/stiffness of roof structure

**STRUCTURAL IMPROVEMENTS AFTER STRENGTHENING:**

- In-plane stiffness of the roof is improved.
- Global seismic behavior of building is improved (because of the rigidity of stiffer roof).
- Roof structure vulnerability is reduced.

**STRENGTHENING INTERVENTION DESCRIPTION:**

This is an intervention on horizontal structure (i.e. roof) and is applied to the poorly built roofs that are made up of steel or timber joists. These roofs lack in plane stiffness due to the poorly connected joints and absence of diagonal elements.
As an intervention, diagonal bracings (timber or steel elements depending on the material or existing roof structure) are installed to improve the in plane stiffness of the roof structure. These bracings should be connected well to the rafters and purlins at the joints using steel straps and/or nails. Furthermore, if the existing connections at joints are not adequate or deteriorated, these should also be strengthened using straps and/or nails. For more information on roof strengthening, refer to NRA (2017).

**ILLUSTRATIVE FIGURES:**

**Light steel roof structure in an LBM school building in Nepal (Copyright: The World Bank).**

**Illustration of improvement of joints in timber roof structures using straps and nails. (Reproduced from NRA, 2017).**

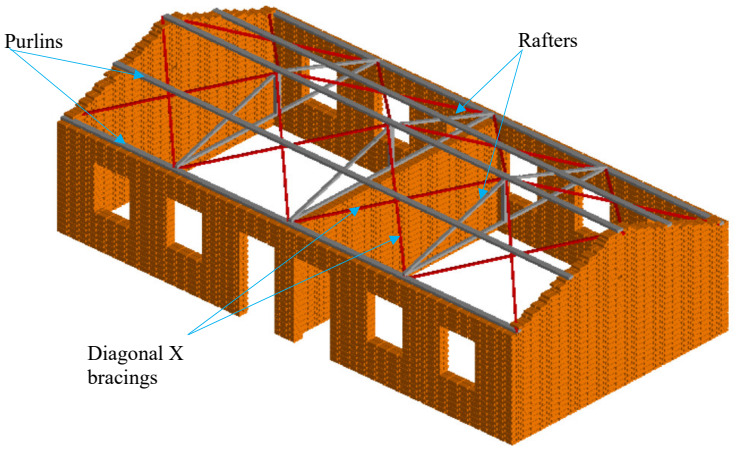


**Illustration of improvement of flexible diaphragm type roof structures (steel or timber structure) using diagonal X bracings. Red colored elements show the retrofitting intervention.**

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**PRECAUTIONS AND LIMITATIONS:**

This intervention requires skilled carpenters. Roof cladding needs to be removed and rebuilt. This strengthening can be done together with roof-to-wall connection improvement works.

**REFERENCES:**

NRA (2017). Repair and Retrofitting Manual for Masonry Structure, Nepal Reconstruction Authority, Government of Nepal, Kathmandu, Nepal.

**Notes:**

- The design details and figures shown here are for illustration purpose only.
- The authors do not assume any responsibility for the consequences of adopting the proposed strengthening solution.
- Experienced structural engineers have to design (dimensions, details and material specifications) and supervise the interventions for each application case.