Reinforcing masonry by attic curbs.

IS IT:

- [ ] *Product*
- [X] *Technology*
- [ ] *Equipment*

APPLICABLE FOR:

- [X] *Restoration*
- [X] *Rehabilitation*
- [ ] *New Construction*

APPLICABLE ON:

- [ ] *1. Foundations and underground structures*
- [X] *2. Vertical structures*
- [X] *3. Horizontal structures and vertical connections*
- [X] *4. Roof and terraces*
- [ ] *5. Façade and building envelope*
- [ ] *6. Finishes and completion elements*
- [ ] *7. Integrated services*
- [ ] *8. General strategies for building recovery*

Related companies: *No companies; university research; structural study.*

DESCRIPTION

The reinforced masonry curbs prevent the perimeter walls overturning in an historic building, increasing their safety in the event of an earthquake.

WHY TO USE

IMPORTANCE OF ATTIC CURBS IN SEISMIC IMPROVEMENT OF HISTORICAL BUILDINGS.

The seismic behavior of a historic building with stone or brick walls and timber floors is very different from that of a modern reinforced concrete structure. The most dangerous phenomenon is in fact constituted by the collapse of the perimeter walls following their overturning out of the vertical plane.

It occurs generally as the masonry is made of poor stone or brick, that is very common in historic buildings, and not properly clamped with the contiguous walls when the seismic shock occurs perpendicularly to the masonry, with a direction from the inside to the outside. Often the instability, also, involves the main beams of the floors, the trusses and the purlins of the masonry, that cause the collapse of the entire building. To solve such problems drastically, and increase the seismic safety of a historic building, there are two basic remedies: tie rods and chains with key heads at the intermediate floors and top curb immediately under the wooden framework of the roof.

The main function of the summit curb is in fact precisely that of pursuing the box-like behavior of the building by preventing the overturning of the individual walls, hindering the extraction of the trusses from their seats, and distributing the seismic stresses more evenly among all the load-bearing walls.

HOW TO USE AND APPLY

A top masonry curb can be built with various materials: the most common are wood, metal (usually steel profiles), reinforced concrete and reinforced masonry.

Each device (material) has proper characteristics of strength and weakness.

Until the 1990s, reinforced concrete curbs were widespread, which at the time were considered particularly effective. However, that was disproved by the latest earthquakes.

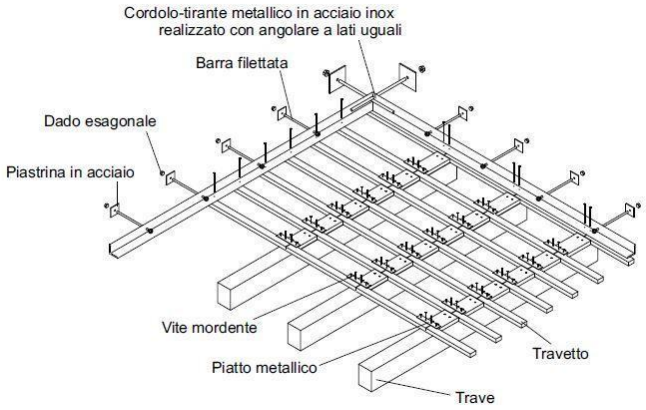

Fig.1: Axonometric section of the curb-tie made with a metal profile. © *https://www.teknoring.com/guide/guide-edilizia-e-urbanistica/tecniche-intervento-edifici-muratura-cordoli-profili-metallici/*

Fig.2-3: C-profile steel curb.

© *https://www.ediltecnico.it/74874/cordoli-cemento-armato-errori-correzioni/ ; http://www.resinproget.it/quiete.html*

Fig.4: Wooden tie-rod beams in the drum of a church in L'Aquila, Italy, after the earthquake.
© *https://www.corriere.it/economia/16_agosto_26/censimento-catene-45-miliardi-salvare-centri-storici-20586eb8-6b03-11e6-a743-cbace9857496.shtml*

Fig.5-6: Earthquakes in Italy and damage from reinforced concrete curbs. inserted in the load-bearing walls.
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The main disadvantages are two: one conservative and one properly structural. First of all, the construction of a reinforced concrete curb is a very invasive and practically irreversible intervention, explicitly contravening some basic principles of architectural restoration. It is also much more rigid, resistant and heavier than brick or stone masonry. That might cause the so-called beam effect: during a seismic shock the curb and the underlying masonry undergo various relative displacements generating localized bending and traction stresses poorly supported by the masonry, with good mechanical resistance to compression but negligible in traction and bending. The effects can lead to the total collapse of the areas in which the beam effect is greater, generally the cantonal ones.

In the most serious cases, on the other hand, the collapse of the entire building can occur with the crumbling of the stone walls and the fall to the ground of the summit curb which tends to remain intact. However, the insertion of a reinforced concrete curb in an existing building should not be excluded, but must be carefully evaluated case by case.

Conversely, wooden or steel curbs have the great advantage of being easily removable and therefore reversible; moreover, they have excellent tensile strength and high elasticity.

However, they present some criticalities linked - above all - to their difficulty of execution in stone masonry with disordered texture or, vice versa, of squared stone ashlars and in the presence of decorated cornices and/or particularly complex wooden roofing carpentry. Their execution must therefore be entrusted to expert brickmen.

WELL DONE CURBS IN REINFORCED MASONRY

The construction of a reinforced masonry curb is easy in a building with solid brick walls with a thickness of at least three heads, slightly more complex in disordered stone masonry with adequate thickness and decidedly laborious in walls of square segments. The insertion in brick walls with one or two heads is instead impossible due to the insufficient thickness. Generally, a reinforced masonry curb is built with solid bricks preferably salvaged or manufactured by hand, natural hydraulic lime mortar and steel rods with improved adhesion, normally used in reinforced concrete structures.

In a masonry made of squared stone segments, the curb is made up of custom-made elements suitably sized for the insertion of the reinforcement. Such an option is, obviously, more expensive.

It is also necessary to avoid cement mortar because it contains a high percentage of soluble salts that could favor the proliferation of efflorescence and sub-

efflorescence, with consequent disintegration of the mortar joints of the original masonry.

The reinforcement is normally formed by four longitudinal bars with a diameter of 16 mm and thinner brackets (for example with a diameter of 8 mm) with a pitch of 25-30 cm, necessary to avoid the opening of the bars of the main reinforcement.

The brackets must be closed and hooked correctly to the main armature with hooks folded inwards at an angle of at least 135°; while the ends of the longitudinal rods must be overlapped and welded for a length of at least 80 cm.

In correspondence to the corners of the building and the perimetral wall with the neighboring property, it is also advisable to extend the reinforcement bars outside, anchoring them to the masonry with plate or post-key caps. The total height of the curb generally corresponds to 4 rows of bricks, equal to about 25 cm, or to one or more courses of squared ashlars.

An excellent alternative solution, very effective as it allows the load-bearing structure of the roof to be anchored to the curb, considerably increasing the seismic safety of the entire system, involves the use of two further longitudinal iron bars above the structural planking, or to the broken brick bricks: their main function is anchoring the joists of the small frame transforming them into very effective auxiliary tie rods/struts.

These additional irons are held in position by special high brackets, regularly alternating with the usual ones with a pitch of about 50 cm. The anchoring of the heads of the trusses is finally guaranteed by stainless steel strips, nailed or bolted to the wood and hooked to the brackets of the curb.

CONSTRUCTION/EXECUTIVE PHASES

1) Complete disassembly of the top roof.
2) Demolition of the original masonry to a height of about 50 cm at the height of the wooden framework of the roof, especially of the truss heads.
3) Execution of the lower portion of the curb, if in bricks, by two lower irons of the main reinforcement and by two rows of bricks placed in the fascia with the function of formwork.
4) Laying of the second and third courses of bricks, arranged at the head, i.e. perpendicular to the masonry and adequately staggered.
5) Laying the two upper bars of the secondary reinforcement and closing the brackets, taking care to prepare the high brackets for the further work phases, if the roof structure needs to be connected to the top curb.
6) Assembly of the roof trusses, inserting between the reinforcement meshes and making the connections with the metal strips.
7) Filling of all cavities with natural hydraulic lime mortar and completion of the last courses of the masonry.
8) Reassembly of the top roof and closing of the upper brackets.

TECHNICAL CHARACTERISTICS

N/A

RECOMMENDATIONS AND OTHER INFORMATION

N/A

EXAMPLES

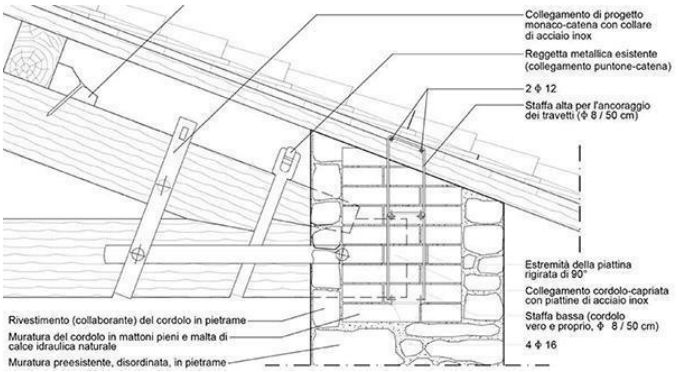

Fig.7: Reinforced masonry curb and connection with the roof. ©*Arch. E. Matteuzzi*

Fig.8: Reinforced masonry curb.
© *https://www.ingegneriavalsecchi.it/portfolio/pieve-di-san-bartolomeo/*

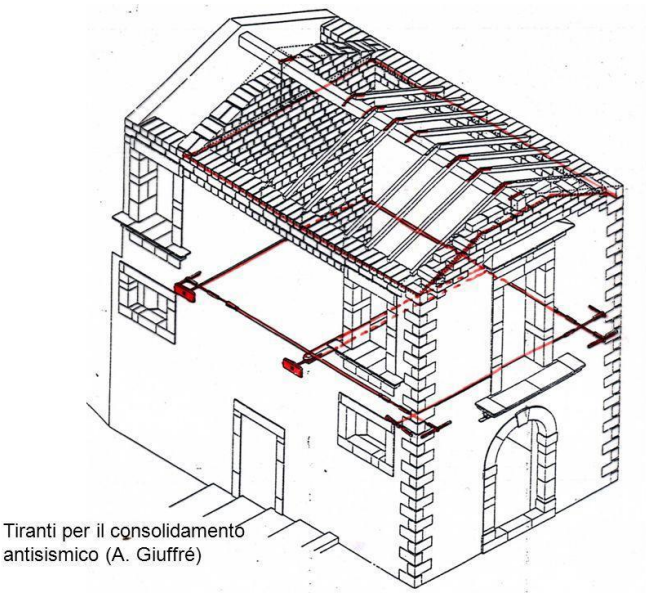

Fig.9: Tie rods for anti-seismic consolidation. © *A. Giuffrè*

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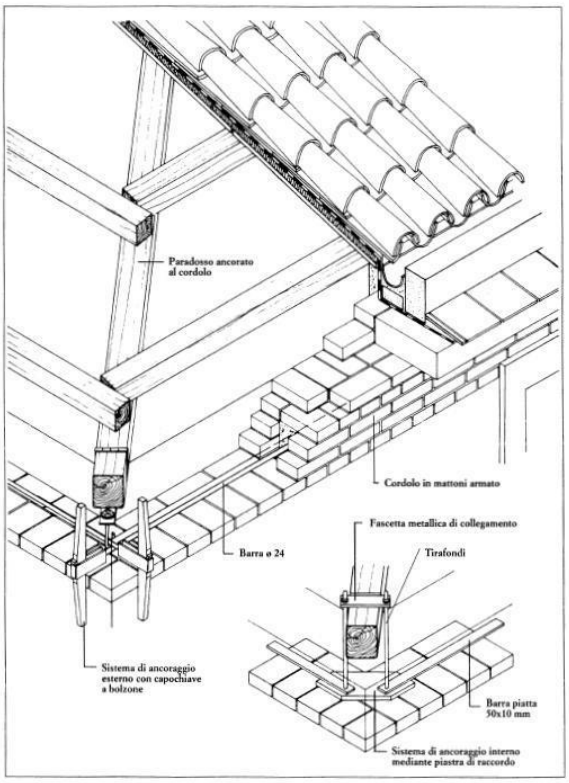
WEBSITE OF THE COMPANY

N/A

IMAGES AND CAPTIONS

Fig.10-11: Reinforcement bars of a reinforced masonry curb. *©Vincenzo Fazio*



Tav. 17. INTERVENTI DI PROGETTO.

Tav. 18. CORDOLO MURARIO DI SOMMITÀ E ANCORAGGI DELLE ORDITURE DI COPERTURA
La tavola illustra il particolare di un cordolo armato in muratura di mattoni, realizzato mediante lo smontaggio della sola porzione sommitale delle pareti esterne e il riuso delle cornici lapidee. Si propongono due sistemi alternativi di ancoraggio angolare dell'armatura corrente del cordolo: con capochiave esterni a bolzone oppure con piastra interna di raccordo. In entrambi i casi la trave di paradosso è ancorata all'armatura del cordolo mediante staffe e tirafondi metallici.

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Fig.12: Wall curb and anchoring of the wooden roofing structures. ©*A. Giuffrè*

Fig.13: Steel bars of a reinforced masonry curb. ©*Vincenzo Fazio*