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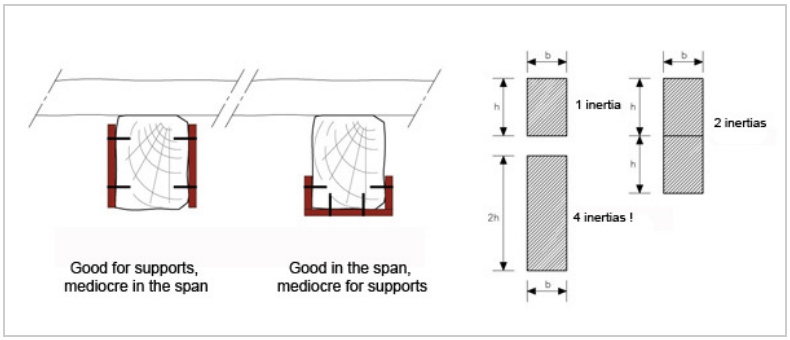
III. Beam reinforcement techniques

III-1. A few useful basic reminders on the subject of structural design and reinforcement



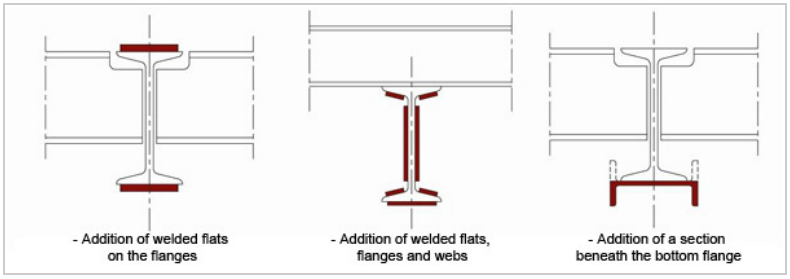
The talented late 20th century design engineer, Peter Rice, who designed such prestigious structures as the bioclimatic greenhouses at La Villette, the Pompidou Centre, the Louvre glass roofing, Kansai airport, the Lloyd's building in London… wrote, prior to his untimely death, that *technical performance is not attained when you have added the last possible component to your structure but, on the contrary, when you have eliminated the last unnecessary component. This creates an impression of structural purity that, to the uninitiated, gives the appearance of great simplicity!*

This quotation draws to our attention the judicious use of material. When reinforcing structural elements, it is helpful to properly understand where the additional material is most shrewdly employed, where it will achieve its full potential.

In certain cases, such as earthquake-resistant design, unwise addition of material can result in the weakening of the structure. For example, increasing the rigidity of a short column by the addition of structural elements will irretrievably result in a more vulnerable structure. This fact sheet which introduces some basic principles of stress analysis is no less useful for all that inasmuch as the pre-implementation study is critical to the success of a reinforcement operation.

Pierre Engel for www.constructalia.com

III-2. Reinforcement of existing steel sections by the addition of flats or welded sections



In the case of floors, reinforcement of the initial steel section is performed by the addition of steel flats and/or sections, which are fastened to the original beam by welding, bolting or bonding. This bracing is generally located beneath the bottom flange, or possibly on the web of existing sections. The top flange may also be reinforced when it is accessible.

In general, lack of rigidity in beams is corrected by adding flats on the flanges, enabling the inertia of the new section thus created to be increased to the maximum. Low shear strength is addressed by the addition of bracing on the webs in zones subject to high shear stress such as supports. These additions of steel components must take account of metallurgical compatibility between materials, particularly if one wishes to make use of welding. These steel floor reinforcement techniques involving the addition of steel flats are also employed for the permanent reinforcement of steel frame elements (see the following chapter/fact sheet).

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III-3. Consolidation of existing steel sections by the addition of flats or welded sections

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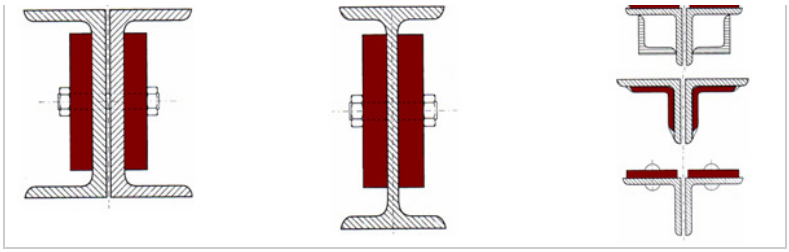
- Fact Sheet N° III-1 A few useful basic reminders on the subject of structural design and reinforcement
- Fact Sheet N° III-2 Reinforcement of existing steel sections by the addition of flats or welded sections
- Fact Sheet N° III-3 Consolidation of existing steel sections by the addition of flats or welded sections
- Fact Sheet N° III-4 Reinforcement of reinforced concrete beams by the addition of steel components
- Fact Sheet N° III-5 Reinforcement of wooden beams by the addition of steel sections
- Fact Sheet N° III-6 Reinforcement or repair of timber floor joists by the addition of steel sections
- Fact Sheet N° III-7 Repair of a wooden floor or frame by providing support for the beams
- Fact Sheet N° III-8 Some illustrations of wooden frame reinforcement using steel sections



This fact sheet shows the example of the restoration and reinforcement of the Parc de la Tête d'Or greenhouses in Lyon. The original components dating from the 19th century were corroded and in places undersized; they had to be reinforced in accordance with the structure's architectural aesthetics and its status as a monument.

The structural components were first exposed by brushing, then the joints (rivets or bolts) were inspected, prior to applying the reinforcements as illustrated in the above figures.

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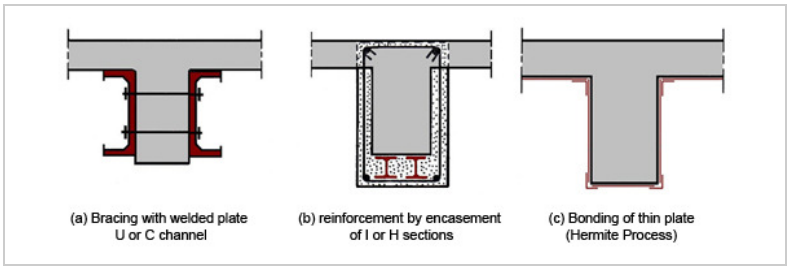
III-4. Reinforcement of reinforced concrete beams by the addition of steel components



The need to reinforce concrete floors arises from deterioration of the encasement and/or the reinforcement (corrosion, fire), increased service loads (change of use) or in order to correct errors committed in the design or execution phases (calculation errors, encasement defects, defects in the concrete employed…). One can also mention the example of the cutting of new floor openings in existing slabs, where the severance of loadbearing members necessitates the installation of trimmer beams (see following fact sheet). While other reinforcement techniques exist (shotcrete, synthetic resins …), steel reinforcement of reinforced concrete beams and slabs is greatly esteemed by professionals because it affords flexibility and highly practical ease of installation. The three techniques illustrated above summarise some possible methods.

Bracing (figure a) a reinforced concrete beam enables it to be reinforced or supported in the case of a floor opening. Figure b shows the reinforcement of a beam by bolstering and encasement using compact sections. Lastly, figure c shows the reinforcement of a beam section by bonding plates using epoxy resin. This technique, still known as the "Hermite process" is also employed for the reinforcement of reinforced concrete bridge decks. However, it must be noted that, due to the fire resistance characteristics of the adhesives, this solution does not enable the provision of a greater degree of fire stability. The addition of a steel beam duly connected (drilling of the slab at the pitch of the studbolts) to the lower face of a slab or beam is also an effective reinforcement solution.

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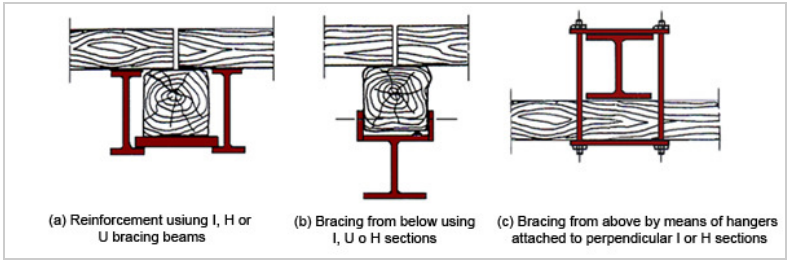
III-5. Reinforcement of wooden beams by the addition of steel sections



Reinforcement of the main beams of old frames can easily be performed using steel solutions. There are many possible solutions. This fact sheet provides some (non-exhaustive) examples. Figure a), where the wooden beam is braced with steel U, I or H sections. When the beam downstand is not a problem, one can also (figure b), insert a beam to support the existing beam. The installation of a sufficient number of connectors (lag screws) has the effect of locking together the timber and steel, resulting in increased inertia which is greater than the sum of the inertias of the two beams.

Lastly, figure c) shows an example of the support of a timber beam by suspension. A steel beam perpendicular to the frame's initial span is fixed into the walls. The timber beams are then secured to this beam, which has a sufficient inertia, by means of stirrups.

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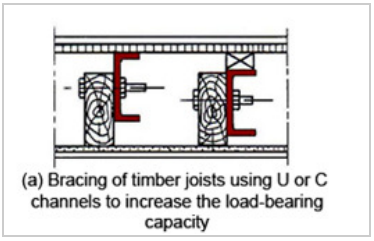
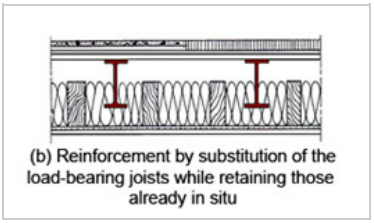
III-6. Reinforcement or repair of timber floor joists by the addition of steel sections

As in the case of frames, the reinforcement of wooden floors by the addition of steel sections is a suitable solution, both to reinforce damaged structures (rotten or worm-eaten), and to withstand increased loads. The reinforcing sections are supported by the existing structure or a supplementary structure (walls, beams…). The above sketches are furnished as examples; they illustrate some solutions for the reinforcement of floor joists that enable retention of the existing ceiling without uninstalling it.



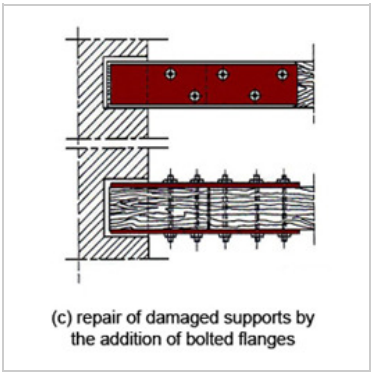
(a) Bracing of timber joists using U or C channels to increase the load-bearing capacity

Figure a) shows an old floor reinforced with "trimmed joists". Steel beam reinforcement is performed using U-type channels, braced to limit the risks of warping and positioned on one or both sides of the piece to be strengthened. Defective joists, often warped, are secured to these new sections.



(b) Reinforcement by substitution of the load-bearing joists while retaining those already in situ

Figure b) illustrates reinforcement without the use of the existing joists that carry only the ceiling. The loads are entirely taken up by replacement steel beams installed in the floor space. Damaged joist supports can be reinforced by the addition of steel flanges.



(c) repair of damaged supports by the addition of bolted flanges

The problem is addressed by establishing a new support in the form of either corbels, columns or wall elements. A new piece of treated wood can also be joined to the defective joist by means of two steel flanges fixed by means of lag screws or by bolting.

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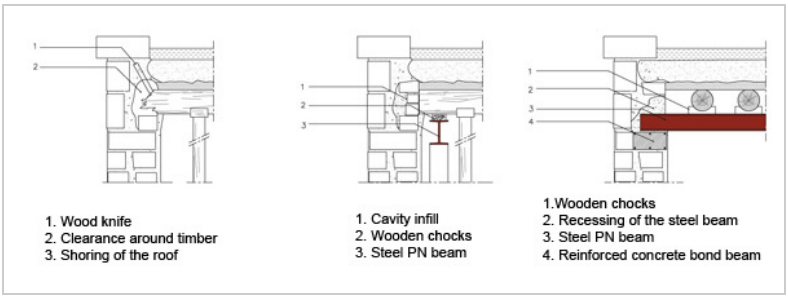
III-7. Repair of a wooden floor or frame by providing support for the beams

The floors and roofs of old buildings were often constructed using roughly squared wooden logs that were set into the masonry with varying degrees of regularity. Loss of watertightness in the roof or simply persistent damp can result in decay of the floor or roof supports with irreversible damage and ultimately the risk of total collapse. After shoring of the structure, cleaning of damaged areas and the treatment of rot, an effective method of reinforcement consists of installing a steel edge beam perpendicular to the affected floor joists or beams.



Carefully underpinned by shoring beneath the timber joists, this IPE or HE type steel beam is set into the adjacent walls, subsequently serving as a support for the joists. In this operation, due to the material's high modulus, the use of steel beams provides rigidity and reduced size.

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III-8. Some illustrations of wooden frame reinforcement using steel sections

a) reinforcements of timber joist at supports

b) Braced timber joist reinforced above supports

c) Bracing of a timber joist using two UPN channels

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