# Structural calculation of L20-2R-GLE staircases

SOLIDARIETA' INTRAPRESA

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Subject:

# STRUCTURAL CALCULATION OF THE MODEL

# L20

**PRIVATE USE**

**-Based on UNI norms 10806 /10810/10812-**

**ATTACHMENT: "Structure and treads calculations"**

*Features:*

Width = 1000 MM

NO. Risers = 16

Riser = 200 mm

Step run = 250 Mm

Live load = 200 daN/mq

Continuous Load = 30 daN/mq

Builder:


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*Forlì, 18 ottobre 2015*

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## 1 TECHNICAL REVIEW AND MATERIALS

The following pages constitute the verification of calculation of staircase L20 main structural prototype scale L20 For the private use only regarding UNI 10804 norms.

The staircase is made of two stringers made from steel plate plasma cut. The stringers can be rectilinear with constant section 150x8mm made of steel S 235 JR.

The staircase is fixed at the beginning and at the ending part the landing, moreover, the side fixings are also included every 4 treads and at every turn.

Wall mountings are made with M10 bars Hilti HY150 or equivalent ones, the wall must be in reinforced concrete or similarity.

The foot traffic surface considered, is made of laminated beech wood slats. The tread is made of laminated beech wood slats 1000mm width, 260mm large and 40mm thick and 220/250 mm for the going. Treads are fixed to the stringers with M8 cl.8.8. screws.

On starting side, the stringers are fixed on the ground with an angle bracket and 2 M10 bars with resin. The staircase is considered hinged to the landing and to the beginning. Treads and stringers tests has been made.

Required connections through welding will be made inside the workshop and welds will be in full penetration.

On external side the railing will not be considered in this review since various types can be applied on the stair in subject.

The stair is 1000mm width, railing included, going of 220/250mm, riser 200mm.

Calculations consider 7 layouts with 16 winder and rectilinear treads:

- Straight/Rectilinear layout: 16 rectilinear treads [R16]
- "L" layout: 3 winder treads and 13 rectilinear treads [P3 R13]
- "L" layout: 6 rectilinear treads + 3 winder treads and 7 rectilinear treads [R6 P3 R7]
- "C" layout: 3 winder treads + 10 rectilinear treads and 3 winder treads [P3 R10 P3]
- "U" layout: 3 winder treads + 3 winder treads + 10 rectilinear treads [P3 P3 R10]
- "L" layout: 13 rectilinear treads and 3 winder treads [R13 P3]
- "U" layout: 10 rectilinear treads + 3 winder treads and 3 winder treads [R10 P3 P3]

All these seven layouts have a horizontal development of 400 cm and height difference of 320 cm, everything obtained with 2/3 side supports depending on layout, they can be substituted by ground supports; moreover every 3 treads there is a wall-fitting, these are intended to be used as stabilizer oscillations.

Side supports are made of interlocked shelves to the wall with plate and plugs to be grouted/cemented into the inside.

The stair is considered to be fixed at the beginning and at the landing side. At the beginning the run is fixed with threaded rods and resin to the foundation/slab, in the same way the landing is fixed to the concrete.

The load situation examined English texts opens an evenly distributed load all over the run.

The material used for this work is:

1) PROFILES: Steel S235 JR EN 10025/95 type (Fe 360 UNI 7070)
2) RODS: Rounded steel S235 JR (Fe 360)
3) ELECTRODES: Joints II UNI 8031 PM 2 type
4) PLATES/SLABS: Steel S235 JR EN 10025/95 type (Fe 360 UNI 7070)
5) BOLTS: Class 8.8
6) TREADS /HANDRAIL/PILLAR: Solid beechwood (broadleaves, D35 category, $f_{m,d}$ = 350 daN/cm2 , $f_{t,o,d}$ = 350 daN/cm2, $f_{v,d}$ = 34 daN/cm2, $f_{c,or,d}$ = 22 daN/cm2, E = 115000 daN/cm2 )

The calculation is addressed only to the verification of self-supporting of the main structure of the stair itself, therefore, any structures on which the scale will be passed and the connections of all rods will need to be properly sized. Seismic actions and dynamic action have not been taken in consideration .

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## 2 REFERENCE TO STANDARDS

This project takes basis from the following standards norms or technical instructions.

| | |
|---|---|
| CNR-UNI 10022-84 | Cold profiled; instructions for use in buildings |
| CNR-UNI 10011-85 | Steel buildings |
| UNI 10812/10810 | Prefabricated Stairs |

## 3 MATERIALS

The sections and semi-finished products used for the structure are made of steel type S235 JR EN 10025/95 - S275 JR EN 10025/95 (Fe 360 B UNI 7070 - Fe 430 B UNI 7070); the characteristics of resistance and the chemical composition are as indicated in the corresponding prospectuses of D. M. 27 /7/87 - 2

The semi-finished products are made with weldable material compatible with the welding process adopted: manual with electrodes homologated according to UNI 5132-74 norm type E44 Class 3 or 4 or semi-automatic process a continuous thread in inert atmosphere Ar-Co 2 with qualified procedure according to UNI 287-288 and later ones. In particular, it shall prescribe welds with corner joints of a section which is not less than 0.8 the minimum thickness of the welds and bead on both sides or joints with full penetration and complete restoration of the section.

The methods of structural welding carried out must be validated in accordance with the referenced standard UNI EN 15614-1:2008 norm " Specification and qualification of welding procedures for metallic materials", the staff for the welds is qualified according to the indications given by the UNI EN 287:2007 norm "qualification tests of the welders - fusion welding – steels".

In particular, it shall prescribe welds with corner joints of a section which is not less than 0.8 the minimum thickness of the welds and bead on both sides or joints with full penetration and complete restoration of the section.

The personnel responsible for not destroyed controls (visual inspections) is qualified according to the UNI EN 473:2008 norm (non-destructive tests - qualification and certification of the staff employed in non-destructive tests) in the possession of 2ND level license.

The bolts used is Class 8.8 UNI 3740 norm with the exception of the threaded bars type steel S235 JR EN 10025/95 norm.

The steps are made of solid wood of beech (hardwood, category Q35, fm,d = 350 daN/cm2 , ft,o,d = 350 daN/cm2, fv,d = 34 daN/cm2, fc,or,d = 22 daN/cm2, AND = 115000 daN/cm2 )

## 4 ASSUMPTIONS OF THE CALCULATION

- In the calculation of verification shall be deemed the structure perfectly mounted without misalignments between the lugs and without defects in mounting such as to make any appreciable tensional effects or instability of the second order;
- The stringer is verified for safety purposes considering the lower section between the various application possibilities, so with section 150x8mm steel S235JR;
- The wall interlocking of the side supports must be on wall in correspondence of reinforced concrete structures non-cracked (fcc < 25 N/mmq), otherwise the support and the seal of the pieces must be checked;
- The verification is applied on the main parts only, for this reason the secondary parts and fittings need to be verified in a separated analysis;
- The stair is considered hinged both landing and departure. The ramp is deemed to be in line and maximum length horizontal free between two supports equal to 2.50 m.
- Width of staircase equal to 1.00 m;
- The check of the 7 layouts is made with at least two side wall-mountings every 4 steps. In case of different installation, you must proceed to the specific verification;
- The calculation of the stress was performed in the hypothesis of null relative movements of structure elevation at the bottom level.
- Permanent loads and overloads are evaluated on the basis of the UNI 10804 norm for prefabricated stairs intended to be for private use service. The load situation examined requires an evenly distributed load on the whole run of 200 daN/mq (private use stairs).
- The stress analysis was performed regarding the hypothesis of null relative movements of structure elevation at the level bottom.

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The calculation for the verification of the safety of structural elements occurs with the methods of Science and Technique of construction. The method of verification is to limit states.

The load situation examined provides an evenly distributed load on the whole the rail of 200 daN/mq (private use stair)

The structural analysis is conducted using the method of displacements for the evaluation of the stress-strain condition induced by static loads. The displacements obtained with the resolution of the system give the stresses and tensions of each element.

The structural analysis is carried out with the finite elements method. The method above is based on the schematic representation of the structure in items related only at a predetermined number of points called nodes.

The unknowns of the problem (in the context of the displacements method) are the components of nodes motion referring to the global reference system (translations according to X, Y, Z, rotations around X, Y, Z).

Seismic action and any dynamic actions have been taken into consideration (the stair is always inserted inside a stairwell of a building to which it is rigidly fixed, since the building is more rigid it transmits horizontal actions).

The calculation is addressed only to the verification of self-supporting of the main structure of the staircase itself, therefore the joints and any structures on which the stair will affect must be designed and verified in a separated analysis.

Load tests according to the UNI 10805, 10806, 10807, 10808 etc. must be made.

## 5 USED SOFTWARE

For the verification of main membering constituent of the structure was used the automatic calculation program ALGOR SUPERSAP.

This program has been checked and there is no perfect compliance with the calculations of maximum.

The program *SUPERSAP* applies the finite elements method for structures of any shape, still loaded and secured, in the context of the linear behavior of the same.

For the secondary membering has been and adopted a manual calculation, method of "limit states".

## 6 MECHANICAL CHARACTERISTICS OF MATERIALS

| | |
|---|---|
| S235 JR EN 10025/95 | Ft = 3400 Dan/cm2<br>Fy = 2350 Dan/cm2<br>FD = 2350 Dan/cm2 |
| Bolts 8.8 UNI 3740 | Ft = 8000 Dan/cm2<br>Fy = 6400 Dan/cm2<br>FD,N = 5600 Dan/cm2<br>FD,V = 3960 Dan/cm2 |
| Solid wood class D35 | FM,d = 350 Dan/cm2<br>Ft,0,d = 350 Dan/cm2<br>Fv,d = 34 daN/cm2<br>Fc,or,d = 22 daN/cm2<br>AND = 115000 daN/cm2 ) |

## 7 STAIR FEATURES

Model: "L20"

Width: = 1000 MM

No. Risers: = 16 No. straight treads = 16

Risers = 200 Mm

Going/run = 250 Mm

Length of the ramp in horizontal L = 400 cm (about 150cm between the two rests)

The staircase is composed of two flat stringers, plate 150x8mm made of steel S235JR.

On the wall-side the stair has wall-fixings every 4 steps on concrete supports.

On the external side the railing is an outer reticular neglected in testing phase and the loading tests since many kinds of railing can be applied.

The foot-traffic surface of the stair, in object, is made with wood steps made of beech. The tread is made of hard-wood of beech 1000 mm length, minimum width 260 and 40 mm thick, useful tread 220/250 mm. These steps are constrained to the ramp stringers by screws made of laminated wood of beech through an appropriate metal bracket.

Step in solid beech wood 260x40mm length of 1000mm.

## 8 LOADS ANALYSIS

### 8.1. PERMANENT LOADS

The weight of the structure is the unique permanent load:

1. Stringers weight $q_1$ = 9,00daN/m
2. Railing weight $q_2$ = 14,00daN/m
3. Solid beech steps weight (700 daN/sqm) thick 4 Cm $q_2$ = 30.00daN/m$^2$

### 8.2. OVERLOADS

A) service loads:

The magnitude of the vertical loads for the service stair according to the UNI 10810/10812 norm is equal to:

$q_v$ = 200 daN/m$^2$

(B) accidental loads:

Wind, snow: not considered because the structure is intended to be for internal use only.

### 8.3. VERTICAL FORCES

We consider the forces due to permanent loads and overloads.

| | | | | |
|---|---|---|---|---|
| 3 | $q_3$ x 0.9 | = | 27 | daN |
| 3 | 1 X $q_2$ | = | 14 | daN |
| 1 | 1 X $q_1$ | = | 9 | daN |

Total distributed qp = 50 daN/m

Total Load:

Weight: $q_{pt}$ = 50/0.9 = 56 daN/m$^2$

Overloads of service: $q_v$ = 200 daN/m$^2$

| | | | |
|---|---|---|---|
| SLS: | participation coefficient | $\gamma_g$ = 1.1 | $\gamma_q$ = 1.5 |
| SLU: | participation coefficient | $\gamma_g$ = 1.3 | $\gamma_q$ = 1.5 |

### 8.4. HORIZONTAL ACTIONS

It is considered a zone 2 seismic regarding EC8 (Euro code 8)

| | |
|---|---|
| Location | Town of FORLI' (FC) (Region EMILIA-ROMAGNA) |
| | City FORLI (FC) |
| | Longitude 12,049 , Latitude 44,217 |

| | |
|---|---|
| Soil Category | Type C |
| Intended use | Staircases |
| Site factor | S = 1.150 |
| Structural Type: | Stainless-steel frame- structure factor 1 |
| Ductility class: | DCM (medium ductility) |
| Structure factor: | Single floor and span structure |

The sizing was performed according to the Approach 2.
The seismic stresses are much higher than those due to climatic loads.

## 9 ANALYSIS AND TESTS SUPPORTED BY CALCULATION CODES

The present report of structural calculation, in accordance with paragraph §10.1 of the MD 14 /01/08, is including a general description of the work of the general criteria and analysis and verification. Moreover, it follows the guidance provided in §10.2 of the same MD regarding analysis and audits carried out with the help of computation codes.

| **Parameters of the structure** | | | |
|---|---|---|---|
| Class of use | Life Vn [years] | Utilisation coefficient | Period Vr [years] |
| II | 50.0 | 1.0 | 50.0 |

The following indicates the origin and characteristics of calculation codes used showing the name, manufacturer, distributor, version and license utilization authorization:

| **Origin and characteristics of Calculation Codes** | |
|---|---|
| Name: | PRO_SAP Professional Structural Analysis Program |
| Producer-Distributor : | 2S.I . Software and Services for Engineering s.r.l. , Ferrara |
| License Code: | License dsi1481 |

A careful preliminary examination of the documentation accompanying the software ***has allowed us to assess the reliability and especially the suitability to specific case***. The documentation, provided by the manufacturer and distributor of the software, contains a comprehensive description of the theoretical bases and algorithms used, identification of fields of use, as well as test cases entirely resolved and commented on, accompanied by the input file needed to reproduce the processing:

| **Reliability of the codes used** |
|---|
| 2S.I . has verified the reliability and robustness of the calculation code through a significant number of test cases in which results of the numerical analysis were compared with theoretical solutions.<br>The whole documentation can be read at: www.2si.it/Software/Affidabilità.htm |

In the following description are indicated some types of structural analysis carried out (static, dynamic, linear or nonlinear) and the method adopted for the resolution of the structural problem as well as the methodologies followed for verification or for the project-verification of sections. There are combinations of load taken and, in the case of non-linear calculations, the load paths followed; configurations designed for the structure in question ***were actually comprehensive for the design-verification.***

| **Type of structural analysis** | |
|---|---|
| Linear Static | Yes |
| Non-linear static | No |
| Linear static seismic | No |
| Linear dynamic seismic | Yes |
| Non-linear static seismic (Prop. masses) | No |
| Static Seismic non-linear (Prop. way) | No |
| Static Seismic non-linear (triangular) | No |
| **Project-verification of the elements** | |
| Steel Project | EN 1993-1-1:2005 |
| Wood Project | EN 1995-1-1:2003 |

| **Seismic Action** | |
|---|---|
| Rule applied to seismic force | EN 1998-1:2004 |
| **Combinations of loads cases** | |
| Allowable Stresses | No |
| SLU | Yes |
| SLV (SLU with earthquake) | Yes |
| SLC | No |
| SLD | Yes |
| SLO | No |
| SLU ground A1 | No |
| SLU ground A2 | No |
| SLU ground G | No |
| Characteristic combination (rare) | Yes |
| Frequently combination | Yes |
| Almost permanent combination (SLE) | No |
| SLA (accidental which fire) | No |

The verification of the safety of structural elements occurs with the methods of building science. The structural analysis is conducted using the method of displacements for the evaluation of the stress-strain state induced by static loads. The structural analysis is carried out with the method of the modal analysis and the response spectrum method in terms of acceleration for the evaluation of the stress-strain state induced by dynamic loads (including seismic ones).
The structural analysis is carried out with the finite elements method. The method above is based on the schematic representation of the structure in related items only at a predetermined number of points called nodes. The nodes are defined by the three Cartesian coordinates in a global reference system. The unknowns of the problem (in the context of the method of the displacements) are the components of motion of the nodes referring to the reference system global translations according to X, Y, Z, rotations around X, Y, Z). The solution to the problem is obtained with a system of algebraic equations linear whose known terms are constituted by the loads acting on the structure appropriately concentrated at the nodes:

**K** * **u = F** **K** = rigidity matrix
**U =** nodal displacements vector
**F** = nodal forces vector

Thanks to displacements obtained with the resolution of the system, the stresses and/or the voltages of each element are then deducted, referring generally to a local triad to the element itself.
The reference system used is constituted by a right-handed Cartesian set XYZ. It is assumed the Z-axis vertical and oriented toward the top.
The elements used for the modeling of the static layout of the structure are the following:

- Element type ***TRUSS*** (Rod-D2)
- Element type ***BEAM*** (Beam-D2)
- Element type ***MEMBRANES*** (Membrane-D3)
- Element type ***PLATE*** (Plate-shell-D3)
- Element type ***BOUNDARY*** (Spring)
- Type Element ***STIFFNESS*** (Matrix of stiffness)
- Element type ***BRICK*** (Solid element)
- Element type ***FLOOR*** (Macro element composed of multiple membranes)

CONFIGURATION OF THE "R16 layout"

| **Modeling the geometry and mechanical properties:** | |
|---|---|
| Nodes | 98 |
| Elements D2 (for rods, beams, pillars…) | 112 |
| Elements D3 (for walls, audiences, shells…) | 0 |
| Floor elements | 0 |
| Solid elements | 0 |
| **Size of the structural model [cm]:** | |
| X min = | 0.00 |
| X max = | 400.00 |
| Y min = | 0.00 |
| Y max = | 100.00 |
| Z min = | 0.00 |
| Z max = | 320.00 |
| **Vertical structures:** | |
| Elements of type rod | NO |
| Pillars | YES |
| Walls | NO |
| Septa (a membrane-like behavior) | NO |

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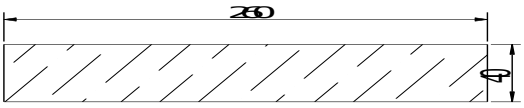
| **Structures that are not vertical:** | |
|---|---|
| Elements of type rod | NO |
| Beams | YES |
| Shells | NO |
| Membranes | NO |
| **Horizontal Elements:** | |
| Floors with hard plan properties | NO |
| Floors without hard plan properties | NO |
| **Type of constraints:** | |
| Nodes rigidly constrained | YOU |
| Nodes constrained elastically | NO |
| Nodes with seismic isolators | NO |
| Foundations punctual (plinths/plinths on pole) | NO |
| Foundations of type beam | NO |
| Foundations of type audience | NO |
| Foundations with solid elements | NO |

| **General Information on the processing and reasoned judgment of acceptability of the results.** |
|---|
| The program includes a series of automatic checks that allow the detection of errors in modeling. At the end of the analysis a self-check identifies the presence of movements or abnormal rotations. It can therefore be asserted that the processing is complete and correct. The results of processing were subjected to tests that prove their reliability. This assessment has included the comparison with the results of simple calculations, performed with traditional methods and adopted, even in first step of proportioning of the structure. In addition, on the basis of considerations concerning the tensional states and settlings very determined, and evaluated the validity of choices made in the schematization and modeling of the structure and actions. You attach at the end of this report summary list of the audits carried out (checks of balance between reactions and applied loads, comparisons between the results of the analysis and those of simplified assessments, etc.).<br>The results of the analysis are completely compatible with the simplified assessments. |

## 10 VERIFICATION STEP

The steps are verified in accordance with the UNI 11002 and 10812 norms.

The steps are made of wood in solid beech 26 x 4.0 cm; dimensions are shown in the figure:




- Geometrical features of the section:

| | |
|---|---|
| Wood: | Solid wood beech |
| Area | 104cm$^2$ |
| Cutting area | 104 cm$^2$ |
| Linear weight | q$^t$ = 10daN/m |
| Modulus of resistance | W = 69.33cm |
| Moment of Inertia | Jx$^x$ = 138.67cm$^4$ |

The verification is carried out in static layout of the beam on two supports according to 2cm of load:

1) Concentrated load in trigonometric P = 200 daN
2) Distributed Load q = 200 daN/m$^2$

L = 100 cm

Resistance of calculation of the step in lamellar beech:

$f_{m,d} = f_{m,k}$ x kmod / $Y_m$ = 213 daN/cm$^2$ = 100 daN/cm$^2$ (reduced for safety purposes)

$f_{v,d} = f_{v,k}$ x kmod / $Y_m$ = 19 daN/cm$^2$ = 10 daN/cm$^2$ (reduced for safety purposes)

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Class of service 1 $Y_m = 1.5$ kmod = 0.8

E = 110,000 daN/cm$^2$

**Cmb 1)**

SLU: Coefficient of participation $Y_g = 1.3$ $Y_q = 1.5$

The load on each step is equal to:

$P' = P \times 1.5 = 300$ daN

$q'$ = weight step x 1.3 = 17 daN/m

Maximum stresses the interlocking:

$Mmax = P' \times L / 4 + q' \times L^2 / 8 = 7080$ daN/cm

$Tmax = (P' + q' \times L) /2 = 158$ daN

MRd = Wx x fm,d = 7600 daN cm > Mmax of project VERIFIED

VRD = At x fv,d = 1140 daN > Tmax of project VERIFIED

**Cmb 2)**

SLU: Coefficient of participation $Y_g = 1.3$ $Y_q = 1.5$

The load on each step is equal to:

$q' = q \times 1.5 \times 0.3 = 200 \times 1.5 \times 0.3 = 90$ daN/m$^2$

$qp'$ = weight of step x 1.3 = 17 daN/m

$qt = q' + qp' = 107$ daN/m = 110 daN/m

Maximum stresses in the middle:

$Mmax = qt \times L^2 / 8 = 1164$ daN/cm

$Tmax = qt \times L = 51$ daN

MRd = Wx x fm,d = 7600 daN cm > Mmax of project VERIFIED

VRD = At x $f_{t,d}$ = 1140 daN > Tmax of project VERIFIED

- The theoretical deflection evaluated on the basis of the loads and the completely reagent section is equal to:

SLE: $f = 5/384 \times qt \times L^4 / (E \times Jx) = 0.04$ cm = 1/2356 L < 1/200 L < 5mm

STEP – STRINGERS JOINT VERIFICATION

The connection is made with 2 M8 screws cl.8.8 :

Ar = 0.38 cm$^2$ n = 2 Tmax = 158 / n = 79 daN

Fv,Rd = 0.5 x Ar x ftb / $g_{M2}$ = 0.5 x 0.38 x 8000 /1.25 = 1216 daN > Tmax of project VERIFIED

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## 11 STRINGERS VERIFICATION

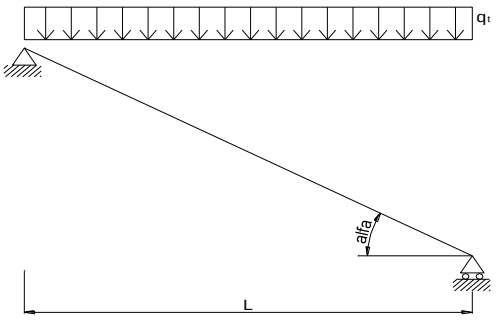
In the worst condition, both permanent loads (leg loops, steps, balustrade), and the loads of exercise are applied to the stringers. They have a straight structure and consists of a single steel element S235JR laser cut with a minimum section 150x8mm. In the verification the wall fixings present every 4 steps are neglected.

Caratteristiche della sezione: mat.
L20 (Fe360/430/510)
150x8 Fe360 fd = 235 N/mm2

| | | | | | |
|---|---|---|---|---|---|
| A = | 1200 | mm2 | h = | 150 | mm |
| Wx = | 30000 | mm3 | b = | 8 | mm |
| Wy = | 1600 | mm3 | a = | 150 | mm |
| ix = | 43 | mm | e = | 8 | mm |
| iy = | 3 | mm | Atx = | 20100 | mm2 |
| | | | Aty = | 128 | mm2 |

Geometria:

| | |
|---|---|
| Luce = | 3000 mm |
| Larghezza rampa = | 1000 mm |
| inclinazione rampa = | 29 ° |
| $q_{acc}$ = | 2000 N/mq |
| $q_{p.p.}$ = | 1000 N/mq |




Carico distribuito sul cosciale $qt=(q_{acc} \times 1,5 + q_{p.p} \times 1,4) \times l/2$ = 2,20 N/mm
Lunghezza equivalente della rampa L' = 3430 mm

componente parallela al cosciale:
qp = qt sen alfa = 1,07 N/mm
componente normale al cosciale:
qn = qt cos alfa = 1,92 N/mm

carico assiale massimo Nm = qp x L'= 3.656 N
momento flettente massimo in mezzaria
Mm = qn x L2/8 = 2.829 N m
- Momento resistente e Resistenza normale della sezione
MRd = Wx x fd = 7050 N m > Mmax VERIFICATO
NRd = A x fd = 282000 N > Nmax VERIFICATO

Nm / NRd + Mm / MRd = 0,41 < 1 VERIFICATO

La freccia teorica valutata in base ai carichi ed alla sezione completamente reagente è pari a:
freccia max = 5xqnxL^4/(384xExJ) = 5 mm < L/300 sezione verificata
$q_n$ (SLE) = $(q_{acc} \times 1 + q_{p.p} \times 1) \times l \times \cos$ alfa = 1,31 N/mm
L'impiego del cosciale risulta verificato in quanto la distanza fra gli appoggi è inferiore a quella considerata.

The result is compatible with the load test enclosed in a condition to load 200 daN/sqm which is obtained a deflection equal to 8.1 mm.

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**2nd Calculation Scheme:** ramp on two rests with concentrated load at the centerline 100 daN. Occurs the deflection (SLE) whereas the ramp on two supports having the following characteristics:

Plate 150x8mm Jx = 225 cm4

Light-space of the horizontal rail L= 400 cm, tilt angle 29° => equivalent length inclined L'= 457 cm

Concentrated load in trigonometric applied for the purposes of safety on external stringer only P = 1 kN

Maximum deflection (SLE) f = P x L'^3 / (48 x E x Jx ) = 0.42 cm = 4.2 mm < 5mm value compatible with the calculation, slightly higher than that found by the tests in that it has neglected the contributor of the other panel (in trials is about 3mm).

## 12 JOINT VERIFICATION LANDING

On landing the stringers of rail are hinged on the concrete floor. The connection of stringer is made with plate, at least 2 blocks M8 x 110 cl. 8.8 HILTI HAS type with resin Hilti HIT-HY 150 or eq.. Mounting must occur at the concrete beam or similar structure.

Tmax = 3 x 1 x (200x1.5 +100x1.3) / 2 / 2 = 323 daN

Verification of blocks M8 x 110 cl. 8.8 HILTI type HAS or eq.

n = 2 Cl. 8.8 $A_r$ = 0.5 $cm^q$

T = Tmax / n = 323 / 2 = 162 daN << HILTI recommended load = 790 daN VERIFIED

## 13 JOINT VERIFICATION AT BEGINNING

On landing the stringers of rail are hinged on the concrete floor or on a foundation made of concrete. The connection of each stringer is made with 2 bars M8 x 250 cl. 8.8 or blocks M8 x 110 cl. 8.8 HILTI HAS type with resin Hilti HIT-HY 150 or eq. Mounting must occur at the foundation in concrete or similar structure.

Verification of 2 bars M8x 250 cl. 8.8 HILTI-HAS type with resin HIT-HY 150 or eq. (grouting products; minimum 11 cm)

n = 2 Cl. 8.8 $A_r$ = 0.5 $cm^2$

T = Tmax / n = 404 / 2 = 202 daN << recommended load HILTI = 790 daN VERIFIED

N = Nmax / n = 323 / 2 = 162 daN << recommended load HILTI = 840 daN VERIFIED

Other connections are for **full penetration welding**.

## 14 CONCLUSION OF THE DIFFERENT CONFIGURATIONS

Following are the main results of the different configurations:

| Type of layout | Ref. l [mm] 1) | q [kN/m²] 2) | $V_{g+q}$ [mm] 3) | Ref. 1/200 [ -] 4) | Q [kN] 5) | $V_Q$ [mm] 6) | f [Hz] 7) |
|---|---|---|---|---|---|---|---|
| "STRAIGHT" R16 | 4000 | 2.00 | 9.9 | 20 | 1.00 | 4.2 | 5.83 |
| "L" P3-R13 | 3200 | 2.00 | 4.4 | 16 | 1.00 | 1.4 | 5.91 |
| "C" P3-R10-P3 | 2500 | 2.00 | | 12.5 | 1.00 | 0.61 | 6.99 |
| "U" P3-P3-R10 | 2500 | 2.00 | 2.1 | 12.5 | 1.00 | 0.65 | 11.74 |
| "L" R6-P3-R7 | 2500 | 2.00 | 5.7 | 12.5 | 1.00 | 1.6 | 9.52 |
| "U" R10-P3-P3 | 3500 | 2.00 | 2.2 | 17.5 | 1.00 | 0.64 | 9.05 |
| "L" R13-P3 | 3250 | 2.00 | 5.6 | 16.2 | 1.00 | 1.3 | 5.81 |

1) Maximum light-space between the supports
2) Value of the operating load distributed
3) Deflection SLE
4) Light space/deflection ratio
5) Value of the concentrated load of exercise
6) Deflection with concentrated load
7) Natural frequency of the system

## 15 ACTIONS ON FOUNDATIONS AND ON MANUFACTURED

The foundations and the consistency of the manufactured must be verified as a function of the following loads transmitted by the staircase to assess in function of the situation.

For safety purposes at the mountings of the stair the consistency of the manufactured must be checked considering the following loads transmitted:

Vertical force: V = 1500 daN

Horizontal force: H = 1000 daN