BRIEF TECHNICAL NOTES ON STRUCTURAL ANALYSIS AND DESIGN

An Informational Series S9708

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STRUCTURAL DESIGN FOR HIGH FORCES

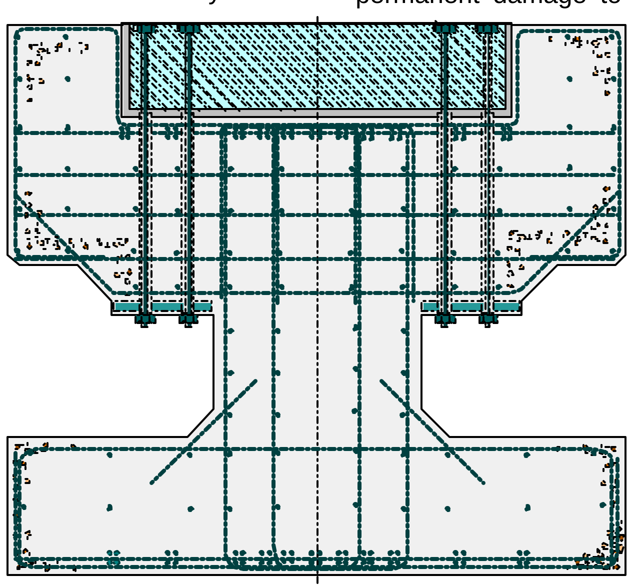
Try to imagine 1.6 million pounds! It amounts to 40 20-ton trucks fully loaded! That's the load capacity of the high force, structural testing machine at Laboratori, General D'Assaigs I Investigations in Barcelona, Spain, built by MTS. The 4 meter deep, concrete beam section resisting these forces in bending was designed by ESI as the supporting backbone structure for the testing machine.

Some of the most recent earthquakes and other catastrophic failures are driving the development of

- more experimental research facilities
- test machines with high force capacity
- strong floors to resist the high loads
- larger monolithic strong walls

Mention Kobe, Northridge or San Francisco Bay. All are sites of fairly recent, major earthquakes resulting in significant structural damage. We all saw the devastation--bridge piers snapped off like matchsticks, buildings totally collapsed, leaning over or torn apart, and all sorts of infrastructure destroyed.

Just when researchers thought they had a handle on building code requirements for seismic forces, along comes Northridge with its high force components and then Kobe with another set of higher force components. George Housner, the famous earthquake researcher, once lamented that each new earthquake shows how very little we really know about the characteristics of strong ground motion events and the overall intensity of seismic forces.



Strong Floor Section - Laboratori, General D'Assaigs i Investigac

In addition to the earthquake problem, it is well known that the number of bridges considered structurally deficient from aging continues to be a major problem requiring load testing in many countries.

MORE STRUCTURAL FACILITIES NEEDED

New technologies and methods for solving these types of problems require a greater understanding of how structural members and connections resist high forces. In the last several years, many universities as well as private laboratories are building new, large-scale facilities to test full-size structural members to complete failure.

Structural laboratory test facilities must be designed and constructed to resist high loads without any permanent damage to the resisting structure itself. Testing to failure gives real meaning to buzzwords like **strong floor** and **strong wall** which are the working surfaces making up the testing area.

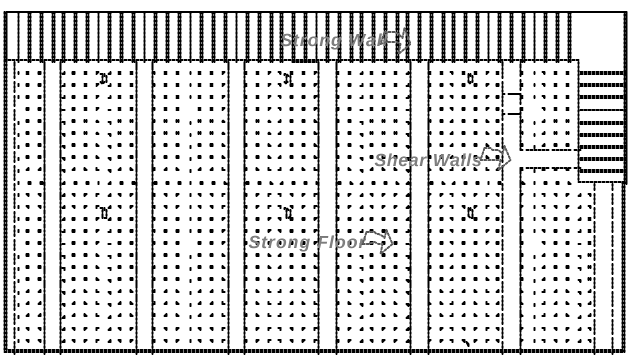
Other elements of the laboratory are the forcing mechanisms or actuators applying the force or displacement. These are mechanical, hydraulically controlled systems capable of applying extremely high forces in tension and compression. They are heavy, rugged pieces of equipment connected through fixtures and frames to the strong floor/strong wall and the structural specimen. The actuators are operated by computerized control systems that simulate real-world forces of nature.

STRONG FLOORS RESIST HIGH FORCE

Most strong floors are designed for testing full-scale components as well as large-scale structural systems. Strong floors are generally planned with a two dimensional, modular grid of tie-down points to encompass a wide range of tests. Many strong floors utilize a box-girder to maximize the stiffness.

Some special purpose strong floors are designed for testing specimens in only one direction on the floor such as in the Laboratori, General D'Assaigs I Investigations in Barcelona, Spain. This one-dimensional strong floor (although it is 4.5 m wide and 12 m long) was designed as the supporting backbone structure for the high force, universal testing machine. The machine is used for static and dynamic testing in tension, compression and bending on loads up to ±7.5 MN (over 1.6 million lbs.) The strong floor is a heavily reinforced I-beam section to handle long specimens in flexural tests.

Two-dimensional strong floors often use a concrete, cellular box-girder concept that usually maximizes the stiffness in only one direction, although they often have a modular grid of tie-down locations to accommodate tests in any direction. Top and bottom flanges of the strong floor are generally two-three feet thick. Floor load capacities can get up to over 300 kips per tie-down point like the large-scale structural laboratory at Hyundai in Seoul, Korea.



Plan View - Large Scale Structural Lab at Hyundai

REBAR SPACING IS VERY TIGHT

Most strong floors (and strong walls) require very dense rebar patterns that must be threaded through embedded tie-down fixtures. Large diameter rebar in each direction are often spaced only 4-6 inches apart while the tie-down fixtures are usually spaced two-three feet in each direction. This tight spacing makes the construction sequence a very time consuming process, which is often underestimated and usually creates considerable delay.

The embedded fixture design itself requires some careful planning and drawing details to simplify and support the rebar placement.

TREND TOWARD LARGER STRONG WALLS

Some of the very early structural laboratories were constructed without strong walls, thus limiting the testing to some degree. In some cases, these labs were built with provisions for large, but movable concrete reaction blocks that could be used as portable walls for testing. Later, some labs were built with smaller monolithic walls along one side or end of the floor. Lately, there has been a noticeable trend towards taller, monolithic strong walls along two sides of the strong floor. Some walls are post tensioned vertically for increased load capacity and crack control. The table below shows features of a few structural labs built in the last 20 years.

Some Recently Constructed Structural Laboratories

Location	Built	Length	Width	Wall Type	Height	Grid Spg
Univ of Texas	1977	54'	42'	Side & End	18'	4' x 4'
Univ-Minnesota	1982	80'	40'	Side	40'	1m x 1m
U-Calif/S Diego	1986	120'	50'	End Wall	50'	2' x 2'
Univ of Nevada	1991	101'	58'	Side-1 Bay	19'	2' x 2'
Daewoo, Korea	1995	38m	17m	Middle	12m	½mx½m
Hyundai, Korea	1996	27m	14m	Side & End	8m	½mx½m

LOAD RATING ANALYSIS IS RIGOROUS

The load rating analysis is part of strong floor/wall design that needs to be quite rigorous to encompass all future combinations of loading that may occur. This can add considerably to the engineering effort and requires detailed finite element analyses of many different load conditions to prevent failure. Load ratings for floors are usually limited in shear capacity while walls are limited by the cantilever moment capacity.

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we have several years of experience in analysis and design of structural floors, buildings, foundations and equipment installation for many industries.

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