THREE TEST PROGRAMS SHOW THAT WELDED REINFORCEMENT GRIDS (WRG) CORRECT UNSAFE DETAIL IN SEISMIC DESIGNS

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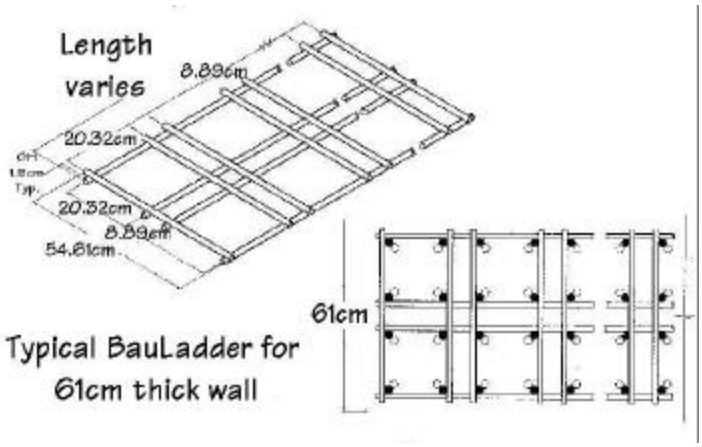

ABSTRACT

Three separate test programs, by Prof. Shamin Sheik of the University of Toronto, Prof. Vitelmo V. Bertero at UC Berkeley, and Prof. Murat Saatcioglu of the University of Ottawa, first uncovered an unsafe seismic design detail, then showed an economical solution, and then showed superior ductile performance.

Figure 1 - Typical BauGrid® Configurations

Key to the solution was the use of Welded Reinforcement Grids (WRG) that not only solved this problem, but also improved the seismic performance of structures constructed with High Performance Concrete (HPC). The third program, by Prof. Saatcioglu, showed that test specimens of 20ksi HPC reinforced with WRG performed with superior ductility.

Single Piece Confinement Reinforcement Solves Little Known Present Day Seismic Code Problem

Constructible inelastic deformability of concrete structures in seismic regions is now possible with the advent of single piece confinement reinforcement called BauGrid® Welded Reinforcement Grids (WRG), manufactured by BauTech, Inc. of San Clemente, CA.

Besides providing engineers with a new way to solve rebar congestion, contractors have found that single piece reinforcement saves significant amounts of labor and construction time. When used at the Long Beach CA site of the 22-story Ocean Villa Project, it was documented that rebar cage assembly labor was reduced by 75%.[1]

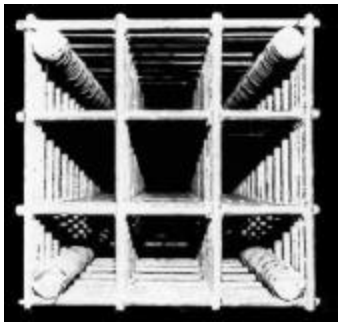

Figure 2 - Test column from research by Prof. Murat Saatcioglu

At the San Francisco, CA, 42-story St. Regis Museum Tower, construction time was reduced by 43%.[2]

Tests performed by Prof. Murat Saatcioglu at the Ottawa Carleton Earthquake Engineering Research Center have proved that 17% less confinement cross section area can safely be

specified when single piece BauGrid® WRG replaces conventional confinement reinforcement.[3]

BauGrid®® WRG is manufactured with a structural weld at every intersection of the crossing high strength (80ksi) steel rods of up to 3/4" diameter. Based upon the improved inelastic deformability shown in the test specimen reinforced with BauGrid® WRG, Prof. Saatcioglu has termed this very desirable property "inter-cell confinement." Inter-cell confinement allows superior ductile performance while using approximately 40% less weight of confinement reinforcement.[4]

Testing Shows Failure of 90° Hooks, Superiority of WRG

Of great interest to engineers are the test results of two research engineers. In 1993, Prof. Shamim Sheikh at the University of Toronto found that conventional crossties with 90° hooks embedded in the concrete cover, failed prematurely as the concrete cover was lost due to spalling as the test specimens deformed inelastically, even with the very labor intensive alternating of hook locations. The test specimen failed as the 90° hooks straightened and failed when the concrete cover spalled.[5]

In contrast to these tests that uncovered this serious but little known weakness in our present day concrete design codes, tests were performed and later reported on (1990) at the University of California, Berkeley by Prof. Vitelmo V. Bertero that showed quite different results.[6]

Concrete test specimens with BauGrid® WRG confinement reinforcement were constructed with the forms in direct contact with the BauGrid® WRG enclosing the rebar. In essence, these specimens had "lost" their concrete cover right from the start of the test cycles. These test specimens performed in a very ductile manner that was quite superior to specimens with conventional confinement reinforcement.

The problem of premature failure of 90° hooks due to concrete cover spalling has now been solved with the introduction of single piece BauGrid® WRG confinement reinforcement.

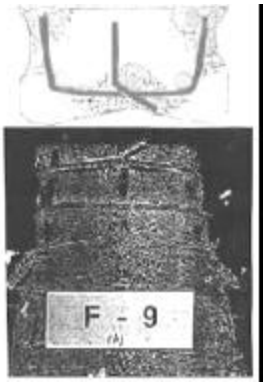

Figure 3 - Failure of conventional hooks in Prof. Sheik's research

High Performance Concrete and High Strength Steel BauGrids® Tested

Of great interest to bridge engineers are the results of separate tests performed by Prof. Saatcioglu on specimen of 20,000psi High Performance Concrete (HPC) reinforced with BauGrids® with High Strength Steel (HSS) with yield strengths of 80ksi.[7] The combination of HPC and HSS BauGrid® WRG as confinement reinforcement now gives the bridge engineer a very strong structural element that has excellent inelastic deformability while still being very constructible.

WRG Reduces Labor and Construction Time

Another benefit that BauGrid® WRG offers the bridge engineer is the significant reduction in labor and construction time that is well documented by contractors who have built tall buildings in seismic regions. At the 42-story St. Regis project in San Francisco a single piece of BauGrid® WRG called a BauLadder® replaced thirty-two pieces of conventional hoop and cross-tie reinforcement resulting in very significant labor savings to the contractor who used the BauLadder®s to make the BauCages™ used in the shearwalls.

Figure 4 - BauLadders in BauCages for 12-story Hard Rock Hotel Under Construction in San Diego

Of additional great value to the contractor was the increased speed of construction when installing the BauCages™ and then placing the concrete. Because each intersection of the crossing rods is a structural weld, the two and three-story high BauCages™ remain very rigid while they are being lifted and rapidly installed at the construction site.

To quickly connect the common vertical edges of the BauCages™ , SpliceGrids™ are used. The SpliceGrids™ are placed at the ends of BauLadder®s, where the vertical rebar has been omitted in the end cells of the BauLadder®s in the two-story high BauCage™. LockingBars™ are then quickly charged by the worker, who stands on top of the two BauCages™ and guides the LockingBars™ as they are charged vertically through the SpliceGrids™ in the shearwall BauCages™ .

Because there are no hooks or laps to obstruct the flow of the concrete, contractors have found that they can place concrete much faster into BauCages™, while at the same time using less labor.

Earthquake and Blast Resistance Testing at Englekirk Structural Engineering Center

Of great importance to bridge engineers is the testing of BauGrid® reinforced structures at the Englekirk Structural Engineering Center at the University of California, San Diego. These structures are designed to resist earthquake forces and will in the future also be tested for their resistance to blast forces.

A full-size seven (7) story concrete apartment module reinforced with BauGrid® WRG is being subjected to simulated strong ground motion recorded in the past during violent earthquakes in several locations in the world. The seismic testing will be done using the world's largest outdoor shake table and a state-of-the-art blast simulator.

With its ±1/8" dimensional accuracy, engineers designing precast concrete structures have found that using BauGrid® WRG is an excellent way to construct precast structures very rapidly.

PRESSS Testing Shows Value of WRG In Precast Concrete

Extensive testing at UC San Diego and the National Institute of Standards and Technology (NIST) of precast concrete structural elements reinforced with BauGrid® WRG showed that the post-earthquake repair costs of this type of post-tensioned precast concrete system would be much less than conventional cast-in-place structures.[8]

Based upon these very favorable test results, the 39-story Paramount Building was constructed in San Francisco. It is the world's tallest precast concrete building to be constructed in a region of highest seismicity. Very constructible long span segmental bridges supported by tall hollow concrete bridge piers constructed with HPC and HSS BauGrid®s seems a very logical design option, based upon the tests at NIST and UCSD and the very rapid construction of the Paramount Building in San Francisco.

When combining 20,000psi HPC and 80,000psi HSS BauGrids®, bridge design engineers now have another way to design bridges that are very constructible and will have excellent and very reliable inelastic deformability in a violent earthquake or blast event.

Now in design is the 60-story 301 Mission St. building in San Francisco which is planned to be rapidly constructed by combining BauCages™ of BauGrid® WRG with self-climbing forms. It is planned to construct the structure at a rate of a floor completed every four (4) days, as was done at the 22-story Ocean Villa project in Long Beach, CA, which is the world's tallest tunnel-formed structure in a region of highest seismicity.

Design engineers and contractors have found that stair shafts surrounded by concrete walls reinforced with BauGrid® WRG can be rapidly constructed using self-climbing forms. These hollow reinforced concrete "tubes columns," called SafeCores™ are designed to resist wind, seismic and blast forces, while also serving as a fire-safe evacuation route for the building occupants.

REFERENCES

[1] Walter Mawby, High Rise Concrete Systems, Inc.

[2] Marie Hunter, Webcor Builders

[3] Saatcioglu, M. and Grira, M., 1996, "*Concrete Columns Confined with Welded Reinforcement Grids*," Ottawa Carleton Earthquake Engineering Research Center - *Report OCEERC 96-05, September*

[4] Saatcioglu, M. and Grira, M., 1996, "*Concrete Columns Confined with Welded Reinforcement Grids*," Ottawa Carleton Earthquake Engineering Research Center - *Report OCEERC 96-05, September*

[5] Sheikh, S. and Tokluco, M., 1993, "Reinforced Concrete Confined by Cylinder Spirals and Hoops", *ACI Structural Journal, September-October*

[6] Miranda, E., Thompson, C.L., Bertero V.V., 1990 "*Cyclic Behavior Of Shearwall Boundary Elements Incorporating Prefabricated Welded Wire Hoops*" - *A Report To Sponsor Baumann Engineering*" EERC College of Engineering, UCB

[7] Razvi, S. R. and Saatcioglu, M. "Stress-Strain Relationship for Confined High-Strength Concrete," ASCE Journal of Structural Engineering, Vol 125, No.3, pp. 281-289,1999.

[8] Cheok, G. S. and Stone, W. C. 1994, "Performance of 1/3-Scale Model Precast Concrete Beam-Column Connections Subjected to Cyclic Inelastic Loads - Report No. 4," NISTIR 5436, National Institute of Standards and Technology, Gaithersburg, MD, June