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One-Piece Welded Reinforcement Grids as Lateral Confinement Reinforcement

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Summary

The development in California, USA over the past twenty years of a unique one-piece confinement reinforcement product called Welded Reinforcement Grids (WRG) has resulted in 2000 tons of WRG being installed in California's tallest concrete building and also the world's tallest precast concrete building in a zone of highest seismicity.

Often more than thirty pieces of hoops and cross ties are replaced with just one WRG resulting in the elimination of rebar congestion, and reduction of time and labor to assemble rebar cages, set rebar cages, set forms and pour concrete because protruding hooks are eliminated and rebar cages with WRG are very distortion resistant.

Recent shake table tests proved that the superior ductile performance of WRG reinforced low rise concrete structures will allow a fifty percent reduction of principal reinforcement steel now required by present day seismic codes.

Very tall concrete buildings are now being rapidly constructed in high intensity seismic regions, at lower cost, when constructed with high strength concrete and WRG manufactured with high strength steel to dimensional tolerances of ±3 mm.

Keywords: welded; reinforcement grids; shearcore; blast; automation; ductility.

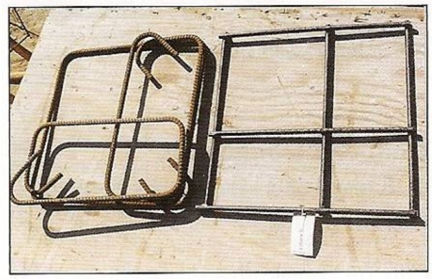

Fig. 2: Conventional reinforcement on left, WRG on right

Fig. 3: Bundles of conventional hoops and cross ties

Introduction

The completion of a 60-story building in San Francisco and two 18-story buildings in San Diego marks a milestone in the 20 year development of a new type of confinement reinforcement for concrete structures in seismic regions (*Fig. 1*).

One-piece welded reinforcement grids (WRG) have been used since 1987 in more than 20 buildings totaling more than 360 floors in twelve cities.

Benefits of WRG

The main benefit that WRG offers is that WRG eliminates rebar congestion, improving constructability. In addition, rebar cages using the WRG reinforcement can be assembled and installed using significantly less time and labor (*Fig. 2*). In one project, construction workers reported a 75% reduction in rebar cage assembly labor.

Because WRG is manufactured with higher yield strength steel and has no hooks and laps, less weight of WRG is used as compared to conventional hoop and cross tie confinement reinforcement

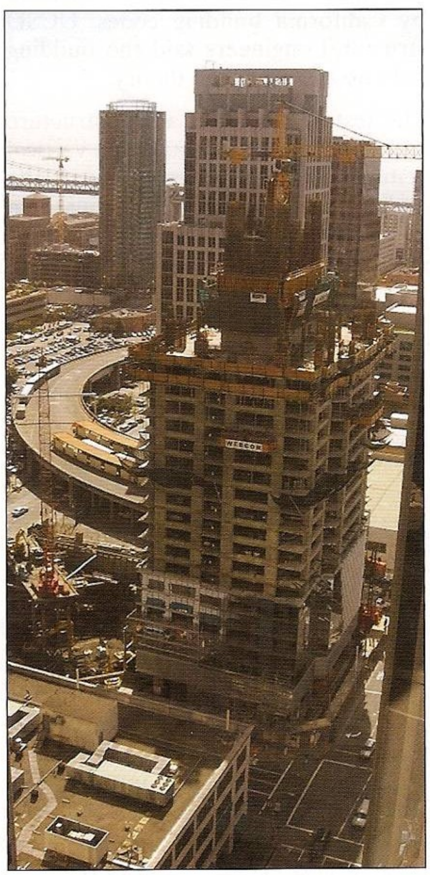

Fig. 1: Sixty-story building at 301 Mission St in San Francisco

(*Fig. 3*). The proven superior ductile performance of WRG reinforced structures[1] permits a design using lower seismic forces, which in turn allows the design mass to be reduced. Results of research conducted to support the design of a 17-story building,[2] allowed the thickness of the shearwalls to be reduced from 254 to 178 mm. As a result the contractor realized a significant reduction in the amount of concrete and steel required for the project.

Contractors have reported that using WRG also allows them to place concrete using less time and labor than with rebar cages of conventional reinforcement (*Fig. 4*).

Due to the tight dimensional tolerances and rigid welded joints of WRG, cages stand taller without corkscrewing, which reduces crane time and allows the contractor to lift multiple stories of column and beam cages at once. This also reduces crane time while setting the rebar cages and installing the forms.

Fig. 4: Bundles of WRG

Reduced Congestion in Elevator Core Walls Speeds Construction

Concrete structures designed to resist earthquake and blast forces require closely spaced transverse confinement reinforcement to obtain inelastic deformability.[3]

Recently, structural engineers and contractors have also found that shearcores with shearwalls around stairwells and elevator shafts are a very economical way to resist lateral forces.[4] The effectiveness of isolated and coupled shearwalls (with coupling beams) in providing lateral drift control, lateral strength and deformability has been established through extensive research. Shearwalls have been accepted by the structural design profession as superior elements against seismic forces. Recent research has also shown that structures designed to resist earthquakes, with capacity to dissipate energy through the formation of stable flexural hinges, also perform well under blast-induced shock waves.[5]

The constructability problem associated with the use of conventional reinforcement is especially severe when constructing these earthquake-resistant concrete shearwalls with boundary elements. When placing concrete through closely spaced conventional confinement reinforcement of hoops and cross ties with hooks, contractors have found that the protruding hooks obstruct the passage of the concrete and vibrators, creating constructability and concrete placement problems.

Furthermore, recent research has indicated that a tradeoff exists between the required amount of confinement reinforcement and the grade of transverse steel used.[6] This research indicates that the spacing of transverse confinement reinforcement can be relaxed if proportionately higher strength steel is used, reducing the congestion of steel cages.

The WRG permits the rapid installation of tall reinforcement cages for these elevator cores. A rapid method of connecting the common vertical edges of the tall cages also accelerates the cage installation and core construction. The closely spaced horizontal WRG ladders with welded joints, give the tall cages large resistance to deformation, providing a perfect system for self-climbing forms.

Shake Table Test Shows Design with 50% Steel Reduction is Safe

A shake table test of a full-size seven-story concrete shearwall module reinforced with WRG boundary elements was undertaken at the University of California, San Diego (UCSD) (*Fig. 5*).[7]

The goal of the 14 January 2006 experiment was to test whether mid-rise concrete apartments, condominiums and hotels can be built to survive powerful earthquakes with less steel reinforcement than currently required by California building codes. UCSD structural engineers said the building held up as well as the theory.

The test showed that a safe structure can be designed with 50% less vertical reinforcement than present-day design codes require when WRG is used in the boundary elements.

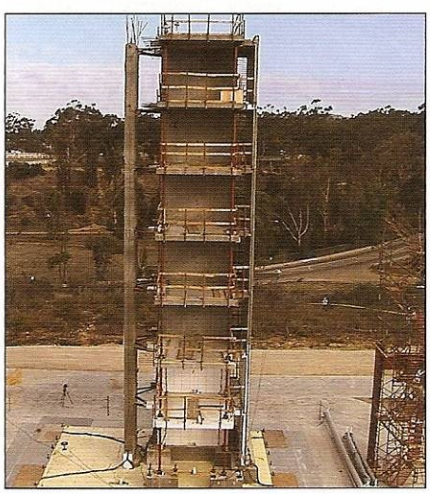

Fig. 5: Seven-story apartment module on shake table at UCSD's Englekirk Engineering Center

High-Strength Concrete Reinforced with WRG Exhibits Excellent Ductile Performance

Recent tests at the Ottawa Carleton Earthquake Engineering Research Center[8] have also shown that test specimens of high-strength concrete reinforced with WRG exhibit excellent ductile performance under cyclic loading. Under the testing regime three high-strength concrete columns were tested (*Fig. 6*). The columns were made with concrete strength f'c = 82 MPa and each using different volumetric ratios of transverse reinforcement using exclusively WRG.

One of the columns had 76% of confinement steel required by ACI 318. The specimen was a 350 mm square section with 12–19,6 mm longitudinal bars (2,95% steel) and nine-cell grids produced using 9,53 mm bars, with a spacing of s = 76 mm corresponding to 3,71% volumetric ratio. This column was subjected to a constant Axial Compression of 20% of Po, where Po is the nominal axial strength of the concrete member at zero eccentricity.

Tested under incrementally increasing lateral drift reversals, the column sustained three cycles of deformation at each deformation level up to 6% without any loss of strength.

When WRG was used to reinforce concrete members, tests showed that 67% fewer rebar couplers can be used while still maintaining excellent ductile performance.

Testing at the National Institute of Standards and Technology[9] and UCSD of precast concrete ductile frames

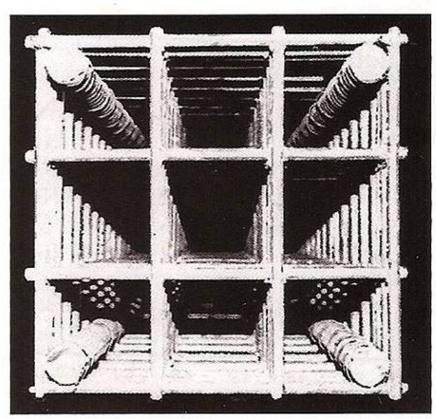

Fig. 6: Tests at University of Ottawa showed reduction in rebar and couplers was safe

having energy dissipating devices and WRG confinement reinforcement has made possible the rapid construction of the world's tallest precast concrete building in a zone of highest seismicity with the recent completion of the 39-story paramount building in San Francisco.

Conclusion

Recent developments in manufacturing methods and quality assurance processes which ensure consistency of high quality welds have made it possible to produce one-piece WRG as a very cost-effective alternative to conventional confinement reinforcement of many hoops and cross ties.

The one-piece WRG also improves ductile performance and constructability while at the same time speeding construction.

The 20-year development of WRG technology is just one example of the team effort of the design and construction industry in the USA today.

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