PERFORMANCE OF I-SECTIONS AS SHEAR REINFORCEMENT IN A LATERALLY LOADED SHEAR-WALL STRUCTURE.

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ABSTRACT

Wall – Slab junction of tall building consisting of shear walls and floor slabs is one of the most highly stressed area. Possibility of junction failure increases with the increase in the height of a building. Particularly this is due to the effect of lateral forces caused by wind and earthquake. The failure is sudden, brittle and without impending warning. Therefore, attempt was made previously to increase the strength and ductility of wall – slab junction by the addition of steel wire couplets twisted together along the periphery of wall- slab junction. However, use of this type of fiber beyond 1.5% by weight is rather uneconomical and with no further appreciable improvement of the performance of junction. Shear reinforcement in the form of vertical stirrups was tried but since the slabs are thin, it is difficult to accommodate such type of reinforcement. Therefore, systematic experimental research has been carried out and based on the results details are presented about the effect of special form of reinforcement consisting of ½ inch wide "I" sections placed at various locations within the slab around the wall periphery. This type of reinforcement seems to have a very favorable effect and therefore the performance of wall – slab junction could be improved to the desired level. A method has been proposed which can be employed for the design of wall – slab junction using this reinforcement.

1. INTRODUCTION

Initially the tall buildings were designed as skeletal structure comprising of beams and columns of rolled steel sections encased in concrete and RCC floor slabs. For tall buildings it is not the gravity load but the lateral force due to wind and earthquake, which becomes the controlling factor in the analysis and design of such buildings. The effect of wind becomes more pronounced with the increase in the height of the building and it acts like a cantilever fixed at base. The skeletal structure particularly proved inadequate to provide resistance against lateral forces and therefore considerable lateral sway of these buildings caused discomfort and sense of insecurity amongst the occupants of these buildings.

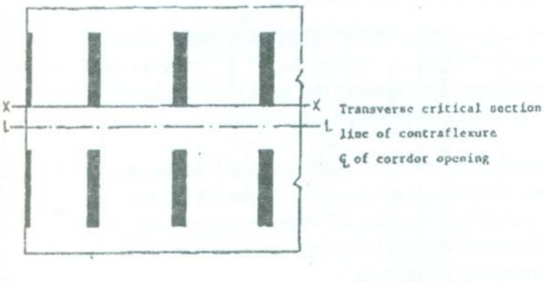

Figure 1: Plan of a typical Shear Wallbuilding showing transverse critical section

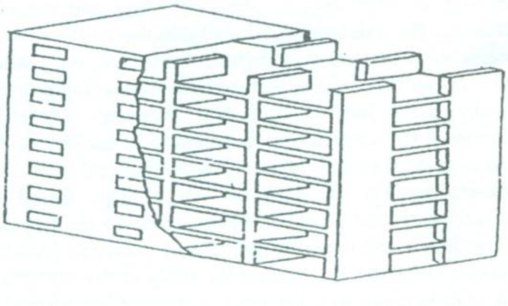

Figure 2: Perspective view of Shear Wall building showing transverse critical section

Therefore the concept of shear wall buildings consisting of load bearing cross RCC walls solely connected by floor slabs, called coupling slabs (with no beams or columns) was put forward. Typical Plan of a slab panel with pair of coupling walls is presented in Figure 1, while perspective view is presented in Figure 2.

A lot of research work has been carried out during last forty years on various aspects of the analysis and design of shear wall buildings. It was realized that full width of floor slab was not effective in resisting the lateral force because the shear induced by the lateral force was uneven with maximum intensity along the perpendicular line joining the inner faces of a pair of cross shear walls.

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Similarly, the bending moment due to lateral forces induced in the slab was maximum at the inner face of the wall and its intensity reduced drastically with the distance from this point. Therefore, the concept of effective width of slab which took part in resisting the effect of lateral forces was put forward by Qadeer & Stafford [1]. They used the numerical method of Finite Differences to evaluate the effective width of coupling slabs. Coupled shear wall with two and three bands of openings were pursued actively by Coul & Suedi [2]. Simplified analysis of coupled shear walls of variable cross-sections was presented by Pisanty & Traum [3], Coull & Wong [4] investigated the matter Design Method (DULDM) for flexural Design of common slabs where he found moment triads with the help of Elastic Finite Element analysis for the ultimate loads but found further by using Finite Element Method. Hago [5] proposed the Direct Ultimate Load design moments from these triads by applying Wood and Armer equations based on Yield Line Theory. The suitability of this method for coupling slabs was later checked by Mahmood [6]. One of the major problems is the huge concentration of shear, bending and torsional stresses in the slab around the wall periphery near its inner face. This may lead to punching failure of slab, which could be sudden, brittle, and without impending warning causing great loss of life and property. Therefore, Mahmood [6] carried out systematic research on the behaviour of wall-slab junction by testing real reinforced concrete models of relatively large size. Based on theoretical as well as experimental research he proposed the method to estimate the strength of wall-slab junction. Ghassan Elnounu [7] extended the study of the strength of wall-slab junction to other wall configurations instead of planar cross walls considered by Mahmood [6] as shown in figure. 3.

Bari [8] made use of vertical stirrups as shear reinforcement in the coupling slabs along the wall periphery to enhance its strength. Results of their findings about Stiffened Coupled Shear walls were presented by Coull et al [9]. Farrar [10] devised a method to measure

Figure 3: Different Wall Configurations

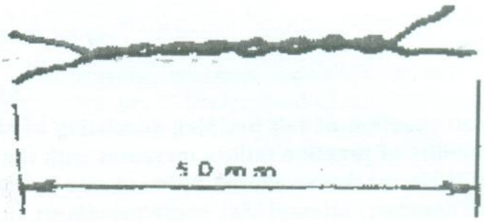

Figure 4: The sketch showing twisted twin steel fibre.

the stiffness of concerte shear walls. Johnson [11] presented his research work regarding the static and dynamic analysis of coupled shear walls. The flexural behavior of coupling slabs was investigated by Muhammad Ayoob [12]. Challal & Nollet [13] worked on upgrading the degree of coupling of coupled shear wall. Dynamic analysis of a RCC shear wall with strain rate effect was investigated by Kazushi & Akira [14]. The problem pertaining to tension flange effective width in reinforced concrete shear wall was studied by Mohammad Hassan & sheriff [15]. Since the thickness of the slab is quite commonly very small as compared with common beams, it is difficult to accommodate vertical stirrups in heavily reinforced coupling slab. Thus it was deemed imperative to provide a different type of reinforcement around wall periphery to strengthen the wall-slab connection so that punching failure could be avoided. Mahmood Memon assessed the strength of wall-slab junction under various circumstances without any shear reinforcement. Noor Ahmed [[16] made use of steel fibre consisting of twisted twins of steel wire 1 mm diameter as shown in Figure. 4. The major parameter was the ratio of fibre reinforcement, which ranged between zero to 2% by weight.

2. PRESENT INVESTIGATIONS

The testing arrangement used for this research is presented in Figure 5, while the " I " section used as shear reinforcement around the periphery is shown in Fig 6 and its location is presented in Figure 7.

The major parameters of study included the location of I-sections, which ranged between 0.5 to 0.65d, the spacing of the pieces and the rate of improvement of the ultimate load. Details of flexural reinforcement in one of the model is presented in Figure 8.

In all six models were tested. Eleven " I " section pieces used as special form of shear reinforcement at the critical section around the wall periphery at a distance of 0.5d from the sides of walls. Where d is effective depth of slab. The shear reinforcement used was 0.74 % of the critical area around the wall periphery. The cracking appeared at 40% of the ultimate load. The cracking progressed as the load increased. Several cracks appeared when the load reached 70% of ultimate load. The cracks were extended and widened when the load reached at 80% of ultimate load.

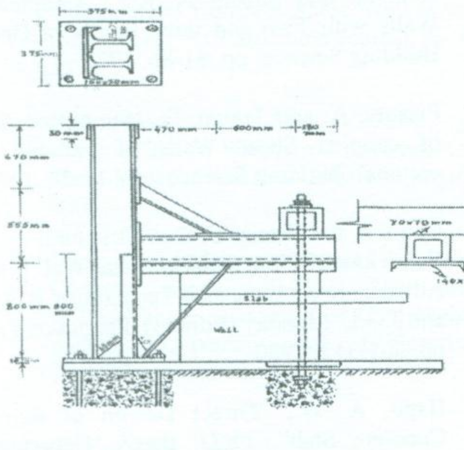

Figure 5: Dimensional details of supporting arrangement.

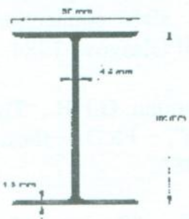

Figure 6: X-sectional view of I-section used as special form of shear

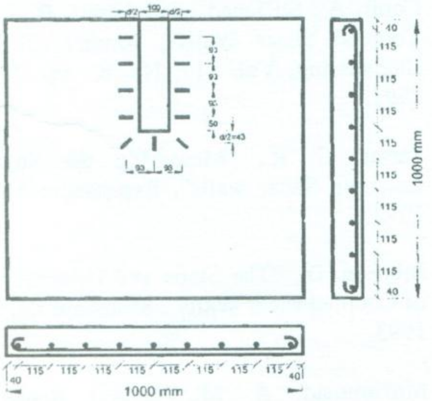

Figure 7: Arrangement of reinforcement and Location of I-sections of the model

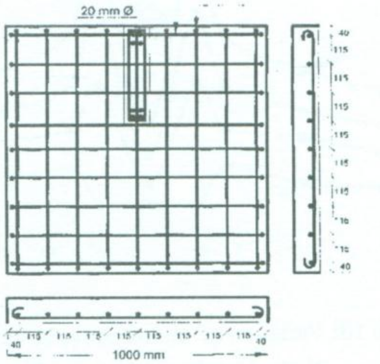

Figure 8: Arrangement of the reinforcement of the model tested

The crack pattern of this model as seen from top , bottom and the back of the model along with the measurement of distance of cracks is shown in figure 9.

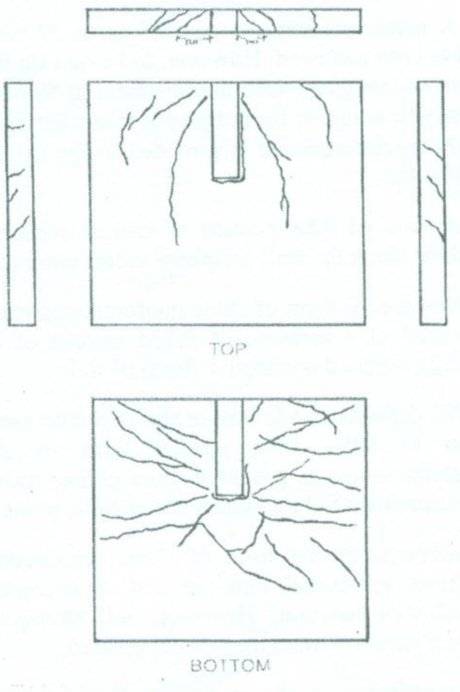

Figure 9: Crack pattern of the slab (top & bottom) with sides and back of model

Clearly this was also the shear failure due to punching of wall through the slab. The failure occurred at a load of 53.04 kN. Strain versus stress at various locations and different stages of loading are presented in figure 10.

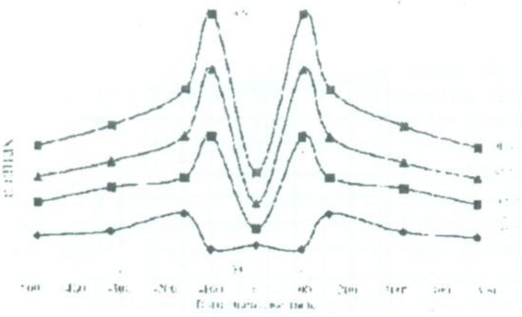

Figure 10: Variation of compressive strain in concrete along trasverse critical section different vstages of loading in the slab of SWSJWSR-02.

3. CONCLUSIONS

Based on the extensive study the following conclusion have been drawn.

01. A maximum improvement of up to 57 percent has been achieved. However, to be on safe side a maximum guaranteed improvement of 50 percent may be assumed for design purpose when special shear reinforcement is provided to the extent of 1%.

02. A ratio of 0.88 percent of critical section for shear along the wall periphery seems optimum.

03. This special form of shear reinforcement may be placed at a distance of 0.75d instead of 0.5d (d/2), where d is effective depth of slab.

04. The deflection at failure of the slab increases by up to 60% when special form of shear reinforcement is provided, thus giving warning of imminent failure, which is a positive point.

05. Although special form of shear reinforcement shows substantial improvement of strength of wall-slab junction, However, full strength of steel shear reinforcement is not utilized.

06. Amendments in the original method have been proposed to take into account the inclusion of special form of shear reinforcement revised method has been presented.

07. From the conclusions and comparison it is observed that the agreement between the actual load at failure and those predicated theoretically using proposed method is reasonable.

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