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# Review on Punching Shear Strength of Slabs

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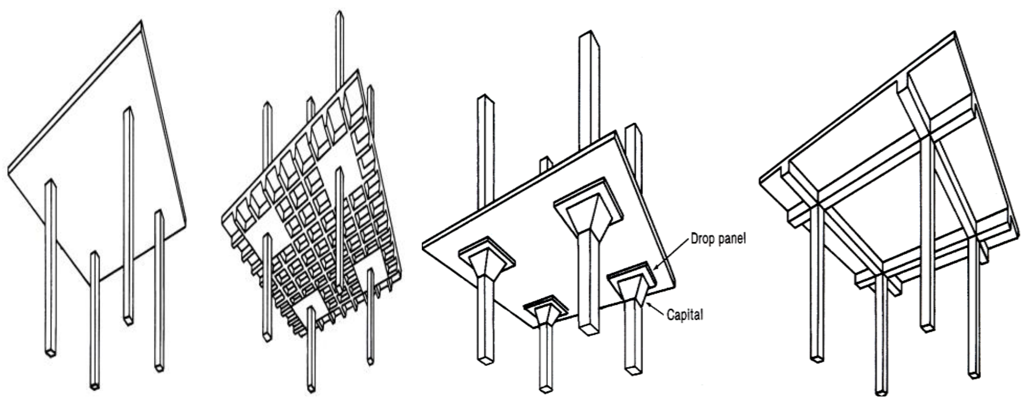
**ABSTRACT:** Slab is one of the component or element in the residential or industrial buildings. Many times the slabs are subjected to uniformly distributed loads and this case may consider in the design process also. Point loads and varying loads are also seen for slabs in special cases. Among many type of loads due to point loads the slabs may subjected to flexure and shear. In the view of shear, one way and two way shear are consider in slab design and checks are also consider during design process. In flat slab design, this is major concern and utmost importance is provided to safe guard the slab against the punching failure. The present review article emphasis on the two-way or punching shear behaviour for slabs elements. The detailed works taken up to 2016 (year) in the arena were noticed in this article.

**Keywords:** Punching shear, Flat slabs, Edge conditions, Strength, Stiffness, Fibres and Cyclic loading

## I. INTRODUCTION

Among many types of reinforced concrete buildings, reinforced concrete flat slab structure is very popular. It consists of flat plate and columns, with no beams between the columns to support the slab. Figure 1 (a) shows a flat plate floor and Figure 1 (b) shows a flat slab with drop panels and column capitals. Figure 1 (c) shows a beam slab floor. In this paper, the flat slab column structures are such as represented in Figure 1 (a). Figure 2 shows an example of a system that consists of flat plates supported on columns. The review article addresses the behaviour, design and retrofit methods for the flat slab structures in brief.




(a) Flat plate (slab) floor (b) Flat slab floor (c) Beam- slab floor

**Figure 1:** Flat slab (plate) floor and beam-slab floor

Flat slab-column structural systems are popular due to reduction of building storey height, easy setting up of formwork and good slab's appearance. However, this type of structure can easily be subject to brittle punching shear failure. When the flat- slab-column connections are subjected to heavy vertical loading, cracks will occur inside the slab in the vicinity of the column. These cracks then propagate through the slab thickness at an angle of 20 to 45 degree to the bottom of the slab. This can lead to punching shear failure of the slab along the cracks (Fig.3). When building or structure subjected to seismic lateral loads, shear stresses in the slab increase due to an unbalanced moment (from horizontal loading), and the slab-column connection is more likely to fail by punching shear.

**Figure 2:** Reinforced concrete flat slab building

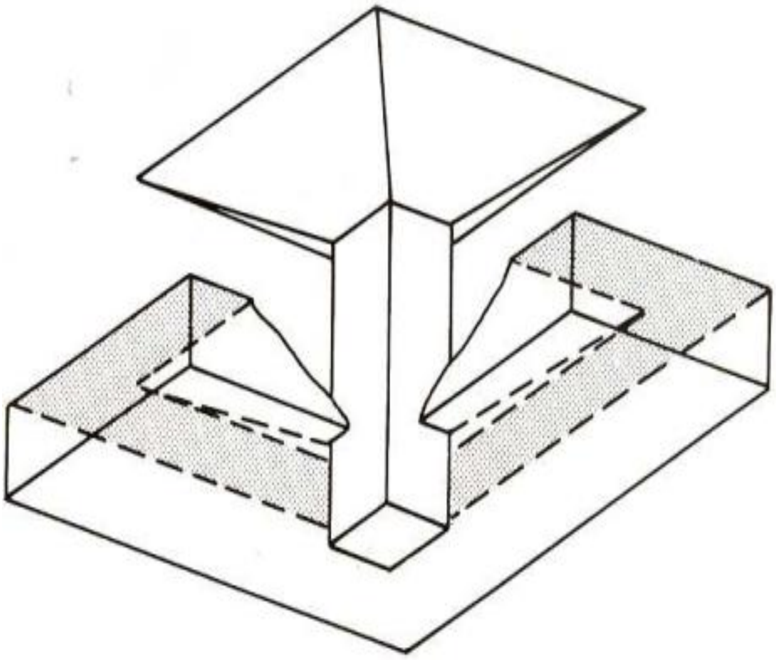


**Figure 3**: Failure surface of punching shear

There have been several cases of punching shear failure in the last few decades. Punching shear failure can happen during the utilization of buildings. For example, in 1962, in New York City, a three year old concrete deck of a plaza, which was part of a roof of a car garage, collapsed suddenly. The roof was supporting 1.2 m deep earth cover with vegetation on it. It was found that the slab punched through a column and there was little damage in other places of the slab.The reason was that the earth on the slab top was saturated and frozen, which increased the load. Moreover, the slab was constructed with insufficient punching shear capacity.

**Figure 4:** Collapse of Skyline Plaza

Punching shear failure can also occur during construction, when the weight of the fresh concrete and shoring are transferred to the adjacent lower stories. These construction loads are sometimes larger than the designed live loads. If the shoring is removed too early, the concrete strength of the lower story may not be sufficient, resulting in lower punching shear capacity. In 1973, the Skyline Plaza (high-rise apartment building in construction) suffered a progressive collapse from the 23$^{rd}$ floor to the basement which caused fourteen workers' death (Fig. 4). The investigation revealed that the failure started from 23$^{rd}$ floor by failure of the slab near one or more columns due to premature removal of shoring and the low punching shear strength of concrete. Openings in slabs are often necessary and are often located near columns. This makes the slab column connections weaker in punching shear. From the introduction it was noticed that many case studies are there about failures. In this view many research works were taken place in the punching shear strength of slabs. Here in detailed past works have been placed to know the research work taken up so far.

## II. REVIEW ON PUNCHING SHEAR

Ibrahim et al. (1988) carried out an experimental program on axis- symmetric reinforced concrete slabs to estimate the punching shear resistance. He proposed a model to estimate the punching resistance. The proposed model can estimate the punching shear behaviour beyond the cracking stage and also the flexural strength capacities. The results are compared with codes of ACI and BS 8110.

Clark et al. (1990) studied the punching shear resistance of light weight aggregate concrete slabs. In the punching shear study the light weight aggregates (oven dry density less than 2000 kg/m$^3$) of Lytag, Pellite, Leca, Fibo and Liapor were taken. The normal weight aggregates which were obtaining from Thames Valley (U.K) were taken as reference for comparison of results. In the experimental study the design densities of the materials tested ranged from 85% to 65% of that of normal weight concrete. Relative to their densities, the light weight aggregate concretes were stronger up to 30% in shear than those made with the reference aggregate. John et al. (1990) investigated about the punching shear strength of reinforced concrete slabs with varying span-depth ratios. For the experimental study, ten slabs were tested. Out of ten five were with flexural reinforcement and five were with both flexural and shear reinforcement. The slab thickness was kept constant. During the experimentation, the supporting diameter was varied to produce different span-depth ratios. Based on the experimental study the authors concluded that for reinforced concrete slabs of constant thickness, the punching shear strength increases as the span to depth ratio decreases below six.

Gilson et al., (1992) conducted experimentations on beam-column-slab connections for evaluation of joint shear. Basically during strong earth quake, beam- column-slab connections can experience severe reversed cyclic loads. If the joints in a moment-resisting frame do not possess adequate strength, the overall strength and stiffness of frame may get adversely affected. The ACI building code and ACI-ASCE committee recommendations for design of beam-column connections were developed primarily from the results of tests conducted on specimens constructed with concrete strength less than 600 psi and nominal yield strength of 60ksi or less. But the authors conducted tests with concrete having compressive strengths greater than 12000 psi and with yield stress of steel 75 to 85 ksi. Based on the experimental observations, they concluded that the joint shear strengths are higher than ACI 318 and ACI 352 design recommendations. Kuang and Morley (1992) reported the Punching shear tests on 12 restrained reinforced concrete slabs. The slab panels were supported and restrained on all four sides by edge beams. The influence of the degree of the edge restraint, percentage of steel reinforcement, and span depth ratio of the slabs on the structural behaviour and Punching shear capacity of the slabs was studied. They observed that the punching shear strength was much higher than those predicted by Johnson's yield line theory, BS 8110, and ACI 318. The enhanced punching shear capacity was a result of compressive membrane action caused by restraining action at the slab boundaries. Desayi et al. (1992) proposed a method to determine the span to effective depth ratios of simply supported (as well as continuous) rectangular concrete slabs. In this method they computed the total deflection of the slab as the sum of the short-term deflection and long term deflection. The calculation of short-term deflections proposed by Desayi depends on the value of deflection coefficient which is given by Timoshenko and Krieger. However, in Timoshenko and Krieger the value of deflection coefficient is given for one condition only. The design charts presented by Desayi are suitable to different conditions.

Kuang Fang et al. (1994) reported the behaviour of 18 partially restrained reinforced concrete slabs with isotropic reinforcements under concentrated load. The primary variables included concrete strength, grade of steel reinforcement, thickness of slab, and the degree of fixity at support. Test results indicated that all the slabs finally failed by punching. The key elements determining the load capacity of thick slabs (115mm) were concrete strength and thickness. The amount of steel did not significantly affect the load capacity, whereas for thin slabs (75mm), the load capacity was primarily dominated by flexural capacity. Slabs having lower reinforcement content exhibited greater intensity and longer existence of the state of compressive membrane action if they had the same span-to-depth ratio and thickness. Nasser Meamarian et al. (1994) described an approach to consider the effects of compressive membrane forces in the analysis and design of pre-stressed and/or Reinforced concrete one way members. The theory of plasticity was applied to find the ultimate load and support reactions for a one way restrained edge slab strip or beam. Modified compression field theory was used in the next step to relate the sectional forces to internal stress, strain, and angle of diagonal cracking at each specified location and to the total deflection. Numerical methods were used in developing a computer program to perform the calculations. The output for 16 one-way strips is compared with test results. Reasonable agreements are found for load, deflection and support reactions at the ultimate load conditions. Neil Hammil and Amin Gali (1994) have conducted experiments on corner slab- column to know the behaviour of punching shear resistance. The experimentation was performed on five full scale reinforced concrete flat-plate connections with corner columns subjected to shear-moment transfer. In the experiment, the variable parameters were amount of shear reinforcement and loading procedure. The design procedure in the ACI 318-89 code and Canadian standard Can3-A-23.3-M84 was discussed. They observed that the equations suggested in those codes were conservative and need improvement.

Hideaki Saito et al. (1995) reported the loading capacities, deformations and failure modes of various types of reinforced-concrete structures subjected to loads applied at various rates. Flat slabs, slabs with beams and cylindrical walls were tested under static, low speed and high speed loading. FE (finite element) analysis was applied to estimate the test results using a layered shell element. The analysis closely simulated the experimental results until punching shear failure occurred.

James Hurst and Gamel Ahmed (1998) presented a computer model to predict the thermal response of carbonate and siliceous aggregate (normal weight) concrete slab specimens subjected to fire. Validation of the model was based on data collected during comprehensive fire test programs conducted by the Portland cement association in the 1960 s. The models ability to replicate the experimental results with good agreement substantiates it as a valuable analytical tool for research and design applications related to concrete fire behaviour. Marzouk et al. (1998) tested the slab-column connections under combinations of gravity and lateral loads to investigate the effect of using high-strength concrete slab on the structural behaviour of the slab-column connections. The variables selected for this study were the strength of concrete slab, the flexural steel reinforcement ratio, and the moment to shear ratio. As the concrete slab strength increases from 35 to75MPa, the shear strength increases by 7%. The use of high strength slab has a significant effect on the load-deflection characteristics for specimens subjected to high-moment. The ultimate deflection increases and the failure mode become less sudden and more gradual, if high-strength concrete slab was used.

Mary Beth Hueste et al. (1999) developed a model for predicting the punching shear failure at interior slab-column connections based on experimental results obtained from previous researchers. A four storey frame office building that experienced punching shear failure during North bridge earthquake was evaluated using this model and the occurrence of punching shear failure was successfully post calculated for the ground motion recorded nearest the structure. The study building was evaluated for three ground motions scaled to the same peak ground acceleration. The building response varied for each record, but in general, it was found that the inclusion of punching shear failure can modify the overall building response in terms of drift, fundamental period, inelastic activityy and base shear distribution.

Alaa and Walter (2000) presented the experimental program as well as the test results related to the flat slabs and shear strength of slab column connections. Based on the test results, the shear strength of slab-column connections in a real slab system with realistic boundary conditions was assessed. The results were compared with the latest provision of ACI, and with a proposed shear strength equation. Manuel Alvarez et al. (2000) presented the results of bending tests on three continuous reinforced concrete slab strips and compared them with calculations according to linear, nonlinear, and limit analysis approaches, as well as with ACI 318 code. It is demonstrated that the reduced ductility properties of cold-deformed and coiled small-diameter reinforcing bars and wires may result in dangerous strain localizations, impairing rotation capacity, permissible moment redistribution, and ultimate strength. A nonlinear analysis method for refined deformation investigations is presented and minimum ductility requirements for reinforcing steel are suggested. Osman et al. (2000) studied the behaviour of high strength light weight concrete slabs under punching loads. In this study, six slabs were tested under central load. Four slabs were constructed with high strength light weight concrete of compression strength less than 70MPa, with steel ratio ranging from 0.5 to 2.0%. Two reference specimens were constructed with normal strength concrete and light weight aggregates and had steel reinforcement ratios of 1 and 0.5%. From experimental results they concluded that specimens with a reinforcement ratio of 0.5% failed under flexure, while concrete specimens with a steel ratio of 1.0% failed under punching shear with some ductility and concrete specimens with reinforcement ratio > 1.0% failed under punching shear. The ductility of high strength light weight concrete slabs decreases as the tensile steel ratio increases.

Mikael Hallgren and Mats Bjerke (2002) conducted non-linear finite element analyses of punching shear failure of column footings. The authors felt that the current design methods and code formulas for the assessment of the punching shear strength are normally based on tests on slabs with relatively high slenderness i.e. with higher shear- span to depth ratios. Column footings normally have low shear-span to depth ratios. Earlier punching tests on column footings indicate that the failure mechanism for punching slabs with low shear-span to depth ratios differs from that of slab with high shear-span to depth ratios. The study also confirms that the punching shear strength of the analyzed slabs strongly depend on the compressive strength of concrete. Menetrey (2002) presented a synthesis of punching failure in reinforced concrete. Experimental results were presented to show the difference between flexural and punching failure. The punching failure mechanism is discussed based on results obtained with numerical simulations demonstrating among others the influence of the concrete tensile strength. Using these results, an analytical model is derived for punching load prediction. The model allows a unified treatment of slabs with various types of reinforcement. Theodarakopoulas and Swamy (2002) presented a simple analytical model to predict the ultimate punching shear strength of slab-column connections. The model is based on the physical behaviour of the connections under load and therefore applicable to both light weight and normal weight concrete. The model assumes that punching is a form of combined shearing and splitting, occurring without concrete crushing but under complex three dimensional stresses. Failure is then assumed to occur when the tensile splitting strength of the concrete exceeded. The theory is applied to predict the ultimate punching shear strength of 60 slab-column connections reported by earlier researchers. The results show very good agreement between the predicted and experimental values.

Antonio et al. (2003) computed the response of clamped slabs when subjected to spatially sinusoidal harmonic line loads using Boundary Element Method (BEM). Frequency and time responses have been computed for slabs with and without lateral confinements for different thickness and varying spatially sinusoidal harmonic line loads. Pilakoutas and Lix (2003) studied about the validation of a patented shear reinforcement system for reinforced concrete flat slabs. The system called shear band consists of elongated thin steel strips punched with holes which undulate into the slab from the top surface. The advantage of the new reinforcement system is structural effectiveness, flexibility, simplicity and speed of construction. The slabs reinforced in shear exhibited ductility behaviour after achieving the full flexural potential, thus proving the effectiveness of the new reinforcement. The results were compared with ACI 318 and BS 8110 codes, which confirm that the system enabled the slabs to avoid punching shear failure and achieve their flexural potential. Both codes are shown to lead to conservative estimates of flexural and punching shear capacities of reinforced concrete slabs. Salim and Sebastian (2003) conducted an experimental study of the ultimate punching load capacity of reinforced concrete slabs restrained by means of incorporating hoop reinforcement. Four reinforced concrete slabs with one control specimen were tested to failure. In addition, the application of plastic theory for prediction of punching shear failure loads in restrained slab is presented. The predictions are in good agreement with a wide range of experimental data of earlier researchers.

Baskaran and Morley (2004) developed a new experimental method to test flat slabs with simple uniform loading with improved boundary conditions. A new form of punching shear reinforcement which will increase the punching shear resistance without affecting the flexural resistance is used. Available experimental methods to test flat slabs are revived to demonstrate the simplicity of the new approach. To show the effectiveness of the both the method and shear reinforcement, some experimental results are included. Ehab EI-Salakawy et.al., (2004) reported the test results of seven full scale reinforced concrete slab-column edge connections strengthened against punching shear. In this study, three slabs contained openings in the vicinity of the column and the other four were without openings .The dimensions of the slabs were 1,540 x 1,020 x 120 mm with square columns (250 x 250 mm). The openings in the specimens were square (150x150 mm) with the sides parallel to the sides of column. The slabs were reinforced with an average reinforcement ratio of 0.75%, except for the two reference slabs. Two different strengthening techniques were considered. Based on the test results, it is concluded that the presence of FRP sheets and steel bolts substantially increase the punching capacity of the connection. Kumar et al. (2004) analyzed the reinforced concrete rectangular slabs for different boundary conditions with corner opening by yield line theory. The ratios of the corresponding lengths of the sides of the opening and the slab are kept the same and the size of opening up to half of the length of the slab is considered. The ratio of the span moments to support moments is kept equal to 0.75. The design tables and the examples to explain the use of the tables for analysis of slab are presented. Kwan (2004) developed a new yield line method that can be applied to any convex polygonal-shaped slab. In this method, the deflections of the slab regions divided by yield lines are measured in terms of the dip and strike angles of the slab surfaces which can define the geometry of all kinematically admissible collapse mechanisms or yield line patterns. The external work done and the internal energy dissipation at yield lines are evaluated as functions of the dip and strike angles and the principle of virtual work is used to determine the corresponding load factor. The final solution is obtained by minimizing the load factor with respect to the dip and strike angles. A computer program to implement this method was also presented. Oliveira et al. (2004) reported the punching shear resistance of high strength concrete slabs with rectangular supports and three different load patterns. Prabhat Kumar and Rajesh Deoliya (2004) found that the finite difference method is very for slabs to simultaneously satisfy the condition of bending and the serviceability is presented. Design charts are provided allowing practical application of this method to enable the design engineer to adjust the steel reinforcement and depth. Design charts are also provided to find out effective depth when the area of steel to resist the bending is just adequate for deflection criteria. Susanto Teng et al. (2004) summarize the research program on flat plate structures conducted jointly by the Nanyang Technological University (NTU) and the Building and Construction Authority (BCA) Singapore. The paper focuses on the punching shear strength of slabs with openings and supported by rectangular columns. Twenty slab specimens were tested under concentrated loads and it was found that the stresses in the slabs were concentrated mostly around the shorter sides of the rectangular columns. Openings reduce punching strength considerably and if the use of an opening is unavoidable, the best place for the opening is along the longer side of the column. Umesh Dhargalkar (2004) derived a closed form solution for designing a simply supported one way slab loaded by a strip load along the span. Young-Ju Kim et al.. (2004) investigated the contribution of the slabs and the effects of three types of retrofit methods. The test result indicated that the strains near the bottom flange of the composite beam connections were several times larger than those of the bare steel beam connections, resulting in a higher potential of fracture. Therefore, the slab effects are detrimental to the seismic behaviour of the connection and should be considered in the design.

Gilbert and Guo (2005) described the experimental program of long-term testing of large-scale reinforced concrete flat slab structures. The results from test on seven Continuous flat slab specimens are presented. Each specimen was subjected to sustained service loads for periods up to 750 days and the deflection, strains, extent of cracking and column loads were monitored throughout. The measured long-term deflection is many times the initial short-term deflection. This effect is not accounted for adequately in the current coded approaches for deflection calculation and control. The results form a benchmark set of data from which more reliable deflection calculation procedures can be developed and calibrated. Sudhakar and Goli (2005) presented the limit moment coefficients for trapezoidal reinforced concrete balcony slabs by using virtual work equations. Ian May and Sarosh H. Lodi (2005) examined the implications of current methods (Yield line analysis, Hillerborgs and Wood-Armer equations) to slab design. They reported that the sandwich approach method proposed by Morley, combined with the Clark – Nielsen equations is more conservative the other current methods. Martin Lemieux et .al. (2005) presented the results of comprehensive experimental investigation to assess the suitability of using thin bonded concrete overlays as an effective rehabilitation technique for concrete bridge decks. Nine 3.3 x 1.0 x 0.2m reinforced concrete slab panels with various configurations and different types of repair concrete were investigated. Papanikolaou et al. (2005) presented results from an extensive testing programme involving a total of 3 reinforced concrete slabs with and without shear reinforcement subjected to a concentrated load in the middle. Shear reinforcement consists of either bent-up bars or closed stirrups. Measured punching shear strengths were compared with strengths predicted from two major design codes (the American, ACI 318 and the European Eurocode2) as well as from two models from the literature, the plasticity Model and a multi parameter empirical model. It was found that predictions by both codes were conservative in the case of slabs without shear reinforcement. Subramanian (2005) reviewed the existing punching shear formula of IS 456 code. Basically the existing punching shear formula does not consider the effect of reinforcement in calculating the punching shear strength. The author of this paper has proposed the formula to estimate the punching shear strength with consideration of reinforcement ratio. The proposed formula is also verified with recent past experimental data which were given by the earlier researchers.

C.K.Kankam and B.Odum-Ewuakye (2006) investigated the flexural strength and deformation of 14 two-way concrete slabs that were reinforced in two directions with babadua (botanical: thalia geniculate) bars. The slabs were simply supported on all four sides and tested under a central concentrated load. Ten of the specimens were tested monotonically while the remaining four were subjected to cyclic loading prior to failure. The span-to-effective depth ratios of the slabs ranged from 13.2 to 26.2. Cracking loads of the reinforced concrete slabs averaged 42% of failure loads predicted for the un-reinforced concrete sections. Experimental failure loads were found to average approximately 170% of the theoretically predicted values. Also the experimental failure loads averaged 148% and 198% of the theoretical punching shear strength of the un-reinforce concrete section under monoto0nic and cyclic loads, respectively. The slabs exhibited high stiffness against deformation prior to collapse through crushing of concrete.

Ran Li et.al., (2007) studied the behaviour of the flat plate slab with carbon fibre reinforced pheolymer( CFRP) rods reinforce in punching shear zone under constant gravity load and lateral displacements in a reversed cyclic manner. Three specimens of interior column-slab connection specimens were tested including one standard specimen without any shear reinforcement, the second one reinforced with CFRP-rods and the third one reinforced with stud rails as the reference to the second one. The slabs were 3000 mm long x 2800 mm wide x 150 mm deep, and were simply supported at four corners. Punching shear failure occurred for the standard specimens at a lateral drift-ratio, lateral drift divided by the length of vertical member of approximately 5%. The specimen reinforced by CFRP-rods had significant flexural yielding and sustained deformations up to a drift ratio of approximately 9% without significant losses of strength and punching shear was not observed in tested specimen. Kyoung-Kyu Choi et.al. (2007) investigated the punching shear strength behaviour of interior slab-column connections made of steel fibre reinforced concrete (FRC). In the steel FRC slab-column connection, the shear force applied to the critical section is resisted by both the compression zone and the tension zone at the critical section. The shear capacity of the compression zone was defined by considering the interaction between the shear and the normal stresses developed at the critical section. The shear capacity of the tension zone was defined by considering the post-cracking tensile strength of FRC. By using the shear capacity, a new strength model for the punching shear strength of steel FRC slab-column connections was developed. J.Hegger et.al., (2007) developed a design model for the punching strength of footings taking into account the soil-structure-interaction. The results of five punching tests on reinforced concrete footings supported on soil are presented. The experimental results indicate that the angle of the shear failure plane is steeper than observed in punching tests on flat slabs and the shear slenderness seems to affect the punching shear capacity significantly. Based upon the findings and test data bank an advance design model is derived, which is based on the BS 8110-1:1997

Ulf Arne Girhammar and MattiPajari (2008) presented an experimental and theoretical study on the effect of structural topping on the shear capacity of hollow core slabs and the adequacy of the shear or bond strength of the non-treated interface. It is concluded that concrete topping can be used to improve the shear capacity of hollow core units. For the test specimens, the theoretical increase was of the order of 35%, which was verified by the tests. R. Vaz Rodrigues et.al., (2008) conducted tests on R/C bridge cantilever slabs without shearreinforcement subjected to concentrated loading. The specimens represent actual deck slabs of box-girder bridges scaled ¾. They were 10m long with a clear cantilever equal to 2.78 m and with variable thickness (190 mm at the tip of the cantilever and 380 mm at the clamped edge). Reinforcement ratios for the specimens were equal to 0.78% and 0.60%. All tests failed in a brittle manner by development of a shear failure surface around the concentrated loads. The experimental results are investigated on the basis of linear elastic shear fields for the various tests. Mark Adom-Asamoah and Charles K.Kankam (2008) investigated two-way concrete slabs reinforced with steel bars milled from scrap metals. The slabs were simply supported on all four sides and tested under a central concentrated load. The average experimental failure loads for monotonic and cyclic loading were 32.8 kN and 26.7 kN, respectively. In addition, the experimental failure loads average 127% and 98% of the theoretical punching shear strength of the two-way reinforced concrete section under monotonic and cyclic loads, respectively. Pierre Koechin et.al, (2008) expressed a failure criterion for reinforced concrete plates and is derived through the kinematic method in the framework of the limit analysis theory. This criterion is expressed in terms of the stress resultant variables; membrane force, shear force and being moment at once. The aim of the authors is to be able to predict the failure of reinforced concrete plate structures in statics or in slow dynamics using directly the internal forces (membrane and shear forces and moment) resulting from a finite-element computation. Aurelio Muttoni (2008) concluded the punching shear strength is a function of the opening of the critical shear crack in the slab. Its influence is assumed to be proportional to the product of the slab rotation times the slab thickness and corrected by a factor to account for the maximum diameter of the aggregate. This failure criteria simultaneously determines the punching load and the rotation capacity of the slab and thus of its ductility.

Jahangir Alam et al. (2009) conducted experimental investigation of edge restraint on punching shear behaviour of RC slabs. A total of 16 model slabs with restrained and unrestrained edges have been tested in an effort to ascertain the influence of boundary restraint, thickness of the slabs on their structural behaviour and punching load carrying capacity.Edge restraint has been provided by means of edge beams of various dimensions in order to mimic the behaviour of continuous slabs. The cracking pattern and load deflection behaviour of the slabs tested have also been monitored closely. Bachir Melbouci (2009) studied mechanical characteristics through proctor test, the CBR test and the shearing tests. The result obtained showed that their characteristics are lower than those of the natural aggregates. Then, we tried to improve them by the following additions (sand, cement and brick) the combination of these materials two to two enabled us to improve some of their physical and mechanical characteristics and bring them near to the natural aggregates. Moreover, repeated shearing of the same sample, in each initial state of stress, high lightened the durability of the aggregates, and particularly their crushing phenomenon. Stefano Guandalini et.al. (2009) confirmed that, due to size effect, the punching strength decreases with increasing slab thickness. At the same time, the deformation at failure decreases. For thick slabs with low reinforcement ratios, ACI 318 is low conservative. The coefficient of variation of the tests is fairly large as well. And also demonstrated that the failure criterion of the critical shear crack theory is applicable both for slabs with and without significant plastic deformations in the flexural reinforcement. Mark Adom-Asamoah and Charles K.Kankam (2009) conducted laboratory tests were on 12 simply-supported one-way concrete slabs reinforced with steel bars that were milled from scrap metals. The slabs were subjected to concentrated line loads at the third points. Two different failure modes of flexural yielding of the tension bar or flexural crushing of the concrete were predicted. The observed failure modes, however, were either one or a combination of modes of tension failure, concrete crushing, diagonal shear, or shear bond failures. On the average, for one-way slabs with span-to effective depth ratios varying between 14 and 24, 37, and shear span-to-effective depth ratios varying between 4,6 and 8,12, a short-term factor of safety of approximately 1,3 against cracking and 0.94 against collapse were obtained from the experimental results.

Sung-Hoonkim and Jun-Hyeok Choi (2010) describes the results of experimental tests on the shear connection of the unfilled composite steel grid deck. To investigate the slip behaviour and the shear strength of the connection, a total of 14 push – out specimens with variables for the number of holes, the area of reinforcements through holes, and the reinforcement diameter, were fabricated and push-out tests were performed. From the test results, each contribution affecting the shear resistance of the connection such as the friction force between the steel beam and the concrete, the concrete dowels, and the shear force due to reinforcement bars, was evaluated experimentally. Hoonhee Hwang et.al. (2010) studied the punching and fatigue strengths of long-span prestressed concrete deck slab used in simplified composite bridge systems exhibiting a minimum number of girders. Ten one-third scale models were fabricated and six of them were subjected to quasi-static test to find the punching strength and verify the validity of available punching formulas. The other models were tested for fatigue strength using moving wheel load to derive a reliable fatigue formula. The test results show that the predictions of the punching formulas considering the effect of prestressing are reasonable and conservative with the formula from Eurocode 2 being the most practical in the design point of view. Fatigue test results reveal that the fatigue strength of the prestressed concrete deck slab is lower than the prediction from the fatigue formula modified from the formula for a reinforced concrete deck slab. Based on the fatigue test results, it proposes a design formula for the fatigue strength of long-span prestressed concrete deck slab.M.A.Eder et.al.,(2010) discussed the modelling of punching shear failure in reinforced concrete slabs using nonlinear finite element analysis. An analytical procedure is presented for simulating punching failure. The procedure is validated for a large –scale reinforced concrete flat slab without shear reinforcement that failed in punching. A parametric analysis is carried out to determine the influence of the key parameters which govern the per performance. The analytical procedure is then used to model the response of a large – scale hybrid reinforced concrete flat slab specimen tested at imperial college London which failed punching. The specimen incorporated a tubular steel column and an ACI 3128 type structural steel spearhead. The results of the analysis are used to gain fundamental insights into the contribution of the spearheaded to the shear resistance, and to assess the reliability of existing design recommendations for structural steel shears heads.

Hong-Gun park et.al., (2011) developed a model to predict the direct punching shear strength of interior slab-column connections without shear reinforcement. At slab-column connections damaged by flexural cracking, it was assumed that the punching shear force was resisted mainly by the compression zone of the critical section. The punching shear strength at the critical section was determined at the intersection between the shear capacity curve and the demand curve. A.PinhoRamops (2011) aimed to improve the understanding of the behaviour of flat slabs under punching load, in order to properly evaluate the effect of the in-plane forces on the punching resistance. Hassan Mohamed Ibrahim (2011) conducted experimental work on 27 square cementitious slabs of 490 x 490 mm simply supported on four edges and subjected to patch load. The slabs had a clear span of 400 x 400 mm and provided with a 445 x 445 mm closed frame of 8 mm diameter steel bar to hold the reinforcement ion place and to act as a line support. The test variables were the wire mesh volume fraction: four expanded and two square types; slab thickness: 40, 45, 50 and 60 mm; and the patch load pattern: square and rectangular. The test results showed that as the volume fraction increased the punching strength of the slabs was also increased. Adding a wire mesh to ordinary reinforcement increases significantly the punching resistance at column stub. Moreover, as the loaded area size increases both ductility and stiffness increases and the bridging effect due to the difference in the reinforcement ratio in orthogonal directions was clearly noticed. L.C.Hoang (2011) investigated the influence of initial cracking on the punching shear behaviour of reinforced concrete slabs. For this purpose, a series of punching tests has been conducted at the University of Southern Denmark. The slabs were quadratic with span of 1050 mm. Slab thickness was 150mm.The initial crack patterns were created by mechanical tension, uniaxial as well as biaxial. The slabs were pre-cracked up to 0.55mm. After cracking and prior to punching testing, the axial loads were removed. The obtained test results show no significant strength reduction compared to the strength of initially un cracked slabs. Ahmed A.Elshafey et.al.,(2011) performed Neural network analysis using 244 test data available in the literature and experiments conducted by the authors to evaluate the influence of concrete strength, reinforcement ratio and slab effective depth on punching shear strength. A wide range of slab thicknesses (up to 500mm) and reinforcement ratios were used. In general, the results obtained from the neural network are very close the the experimental data available. The test results were used to develop two new simplified practical punching shear equations. The equations also showed a very good match with available experimental data. K.Bouiguerra et.al, (2011) presented experimental study on the behaviour of FRP-reinforced concrete bridge deck slabs under concentrated loads. A total of eight full – scale deck slabs measuring 3000 mm long by 2500 – mm wide was constructed. The test parameters were: (i) slab thickness (200, 175 and 150 mm) (ii) concrete compressive strength (35-65 MPa): (iii) bottom transverse reinforcement ratio (1.2-0.35%): and (iv) type of reinforcement (GFRP, CFRP, and steel). The slabs were supported on two parallel steel girders and were tested up to failure under monotone single concentrated load acting on the centre of each slab over a contact area of 600 x 250 mm to simulate the footprint of sustained truck wheel load (87.5 KN CL-625 trucks). All deck slabs failed in punching shear. The punching capacity of the tested deck slabs ranged from1.74 to 3.52 times the factored load (Pl) specified by the Canadian High way Bridge Design code (CHBDC) CAN/CSA S6-06,.Besides the ACI 1440.IR-06 punching strength equation greatly under estimated the capacity of the tested slabs with an average experimental-to-predicted punching capacity ratio ($V_{exp}/V_{pred}$) of 3.l17. L. Nguyen-Minh et.al, (2011) studied the behaviour and capacity of steel fibre reinforced concrete (SFRC) flat slabs under punching shear force. A total of twelve small-scale flat slabs of different dimensions that consisted of nine SFRC and three control steel reinforced concrete (SRC) ones were tested. Effect of steel fibres amount on punching shear cracking behaviour and resistance of the slabs was investigated. The results show a significant increase of the punching shear capacity and considerable improvement of cracking behaviour as we will as good integrity of column-slab connection of the slabs with fibres. The slabs without fibres failed suddenly in very brittle manner, while, the fibre reinforced ones collapsed in more ductile type. At serviceability limit state, a strong reduction of average crack width up to approximately 70.8% of the SFRC slabs in comparison with SRC ones was observed.

Duarte M.V.Faria et.al.,(2012) conducted experimental study concerning the post-punching behaviour of flat slabs strengthened with a new technique based on post-tensioning with anchorages by bonding using an epoxy adhesive. This strengthening technique proved efficient with respect to ultimate and serviceability states. Five slab specimens were tested in the post-punching range and it was found that the post-punching resistance was on average 78% of the punching resistance. This paper reports the development of strand forces and slab displacements from the beginning of the tests, including the bond stresses developed at several stages of the loading process. Long Nguyen-Minh et.al.,(2012) presented experimental study on punching shear behaviour and resistance of post tensioned steel fibre reinforced concrete (SFRC) slab-column connections using unbounded tendons. Eight large-scale specimens were tested, in which fibre amount and concrete compressive strength were varying. The results show that an increasing amount of steel fibres results in an increase of punching shear resistances and energy absorption capacity and contributes to the improvement of slab-column connection integrity. Micael M.G.Inacio et.al, (2012) reported the experimental research carried out to study a strengthening method for flat slabs under punching by introduction of new shear reinforcement. Eight specimens were strengthened with the introduction of prestressed vertical bolts, using different anchorage approaches; large anchorage on surface, small anchorage on surface and small embedded anchorage. A reference specimen, strengthened, was also tested. The experimental punching loads, failure modes and shear reinforcement contribution are compared with the provisions of EC2, ACI 318-11 and MC2010. The tests results show that using small embedded anchorage plates is viable and efficient method for punching capacity improvement. Duarte M.V.Faria et.al., (2012) conducted an experimental study concerning the post-punching behaviour of flat slabs strengthened with a new technique based on post-tensioning with anchorages by bonding using an epoxy adhesive. This strengthening technique proved efficient with respect to ultimate and serviceability states. Five slab specimens were tested in the post-punching range and it was found that the post – punching resistance was on average 789% of the punching resistance. This work reports the development of strand forces and slab displacements from the beginning of the tests, including the bond stresses developed at several stages of the loading process. Hamed Salem et.al, (2012) investigated experimentally the effect of fire on punching strength of flat slabs. An experimental program, consisting of fourteen one-third scale specimens pre-exposed to fire on their tension side and tested under concentric punching, is carried out. The main investigated parameters are the duration of exposure to fire, the concrete cover and the cooling method. Specimens are subjected to direct flame for 1.0, 2.0 and 3.0 h, respectively. Concrete covers of 25mm and 10mm are used for test specimens. Two cooling methods are employed; gradual cooling in air and sudden cooling with water applied directly to the heated surface of the slabs. It was found that exposure of slabs to fire resulted in a reduction of up to 18.3% and 43% in cracking loads and ultimate punching loads, respectively.

Ibrahim M.Metwally (2013) evaluated the punching shear strength of concrete flat slabs reinforced with different types of fibre-reinforced polymer (FRP).A total of 59 full-size slabs were constructed and tested collected from the literature of FRP bars reinforced concrete slabs. The test parameters were the amount of FRP reinforcing bars, Young's modulus of FRP bars, slab thickness, loaded areas and concrete compressive strength. The experimental punching shear strengths were compared with the available theoretical predictions, including the ACI 3128 Code, BS 8110 Code, ACI 440 design guidelines, and a number of models proposed by some researchers in the literature. Two approaches for predicting the punching strength of FRP-reinforced slabs are examined. The first is an empirical new model which is considered as a modification of EL-Gamal et al. (2) model. The second is a Neural Networks Technique; which has been developed to predict the punching shear capacity of FRP reinforced concrete slabs. The accuracies of both methods were evaluated against the experimental test data. They attained excellent agreement with available test results compared to the existing design formulas. M.Hasan Meisami et.al., (2013) conducted experimental study on two-way reinforced concrete (RC) flat slabs under punching shear due to central loading are presented in this paper. All the six RC slabs were designed according to ACI 3128-08 code provisions. Two slabs served as control without any modification while the other four were strengthened in different ways: one with M16 screws and nuts, and three with CFRP rods. For strengthening in each case, 8 and 24 strengtheners were used. A method is proposed for predicting maximum loading capacity of slabs strengthened with CFRP rods and with epoxy resin in drilled holes. The results of the experiments showed that the selected strengthening method was not only able to improve the maximum loading and deformation capacity of the slabs but also avoided brittle failures likely to occur under vertical point loadings. Mohamed Hassan et.al, (2013) investigated the punching shear behaviour of two-way flat slabs reinforced with glass fibre-reinforced polymer (GFRP) bars. A total of 17 full-scale interior slab-column specimens measuring 2500mm x 2500 mm reinforced with GFRP and steel bars were constructed and tested under concentric loads until failure. The test parameters were: (i) reinforcement type (GFRP and steel) and ratio (0.34% to 1.66%): (ii) slab thickness (200mm and 350 mm): (iii) column dimensions (300 mm x 300 mm: 450 mm x 450 mm): (iv) concrete strength (30 to 47 MPa) : and (v) GFRP compression reinforcement crossing the column cross section. The test results were reported in terms of cracking behaviour, deflection, strains in concrete and reinforcement, punching shear capacity and mode of failure. Robert Koppitz et.al, (2013) proposed three-level classification to provide a consistent overview of the wide range of approaches adopted for resistance calculation. Based on this classification, models are evaluated with regard to their applicability for problems specific to the strengthening of existing slabs, such as pre-damage of existing slabs, insufficient anchorage lengths of tensile reinforcement outside the punching zone, new openings in slabs within the punching zone, and the prestressing of posts-installed shear reinforcement. The efficiency of current strengthening solutions is evaluated, suggesting local prestressing as a promising method. **A**ntonioGrimaldi et.al, (2013) evaluated the influence of steel fibres on the punching shear behaviour of bridge slabs. Reinforce concrete slabs with and without steel fibres, having geometry suitable for the simulation of the actual behaviour of bridge deck slabs, have been tested. Furthermore the case of load applied close to the supports, causing shear failure, is experimentally analysed. The obtained results are compared and discussed. JaroslavHalvonik and LudovitFillo (2013) proposed new requirements concerning of maximum punching shear resistance which is based on the factor and punching shear resistance without shear reinforcement. Amir M.Alani and Derrick Beckett.,(2013) presented results concerning the punching shear failure of a 6.06 m x 6.00 m x 0.125 m synthetic fibre reinforced ground supported slab. The paper demonstrated clearly the methodology adopted and the infrastructure used through this investigation. The presented results show clearly that the Punching shear failure values obtained in this investigation are comparable to values reported for the steel fibre slabs under similar conditions. H.M.Afefy et.al., (2013) investigated the structural flexural performance of strengthened one-way reinforced concrete slab included cut-out, six slabs including cut-out adjacent to the central patch load in addition to one slab without cut-out as a reference slab were tested up to failure under incremental monotonic loading. The six slabs including cut-outs contained one control un-strengthen slab along with five strengthened slab. These slab were strengthened using either Near surface Mounted (NSM) steel bars of Externally Bonded Carbon Fibre Reinforced Polymer (FB-CFRP) at the tension side, while four out of them were strengthened by either NsM-steel bars (one slab) or an overlay Engineered Cementitous composites (ECC) material (three slabs) at the compression side. It can be conclude that en anchors for the EB-CFRP sheets along with the surface preparation before installing the ECC overlay are very important parameters in order to guarantee the optimum utilisation for both the EB-CFRP sheets and the ECC overlay material. Bernardo N. Moraes Neto et.al., (2013) developed the design guidelines for predicting with high accuracy the punching resistance of steel fibre reinforced concrete (SFRC) flat slabs, a proposal is presented in the present paper and its predictive performance is assessed by using a database the collects the experimental results from 154 punching tests. The theoretical fundamentals of this proposal are based on the critical shear crack theory proposed by Muttoni and his co-authors. The proposal is capable of predicting the load versus rotation of the slab, and attends to the punching failure criterion of the slabs. The proposal takes into account the recommendations of the most recent CEB-FIP Model Code for modelling the post-cracking behaviour of SFRC. A.Abhdullah et.al., (2013) investigated the effectiveness of bonding non-prestressed and prestressed carbon fibre reinforced polymer (CFR) plates to the tension surface of concrete column-slab connections in both the serviceability and ultimate limit state. For the prestressed plates different prestressing forces were applied to the CFRP as par to the strengthening technique. The structural response of the strengthened specimens was compared with a non-strengthening technique. The structural response of the strengthened specimens was compared with a non-strengthened reference specimen in terms of punching shear strength, deflection profile, strain, crack opening displacement and failure modes. Alejandro Perez Caldentey et.al, (2013) studied the punching shear behaviour of flat slabs with influence of stirrups. Most concrete design codes agree that it is important for punching shear reinforcement stirrups in slabs to engage the tensile longitudinal reinforcement bars. However, due to the practical difficulties that this anchorage detail entails, it has been common construction practice in some countries (including Spain) to place closed stirrups without encircling the main tensile reinforcement. Antonio Grimaldi et.al, (2013) evaluated the influence of steel fibres on the punching shear behaviour of bridge slabs. Reinforced concrete slabs with and without steel fibres, having geometry suitable for the simulation of the actual behaviour of bridge deck slabs, have been tested. Furthermore the case of load applied close to the supports, causing shear failure, is experimentally analysed. The obtained results are compared and discussed. Nuno F.Silva Mamede et.al., (2013) analysed the punching shear of flat slabs through experimental and 3D nonlinear FEA.Numerical results were compared with experimental ones in order to benchmark the FE model and afterwards a parametric study was conducted, changing the reinforcement ratio, slab thickness, concrete strength and column dimensions, running a total of 360 models, where their effect on punching capacity was shown.

T Mohamed Hassan et.al, (2014) investigated the punching –shear behaviour of two-way concrete slabs reinforced with glass fibre-reinforced polymer (GFRP) bars of different grades. A total of 10 full-scale interior slab-column specimens measuring 2500 x 2500 mm with thicknesses of either 200 or 350 mm and 300 x 300 mm square column studs were fabricated with normal and high-strength concretes. The specimens were tested under monotonic concentric loading until failure. The effects of concrete strength as well as reinforcement type and ratio were evaluated. The test result revealed that increasing the reinforcement ratio resulted in higher punching-shear capacity, lower reinforcement and concrete strains, and lower deflections. Francisco Natario et.al, (2014) studied the shear strength of RC slabs under concentrated loads with clamped linear supports. Reinforced concrete slabs without shear reinforcement subjected to concentrated loads near linear supports are usually designed or assessed in shear using design provisions that have been calibrated on the basis of tests on one –way slabs or beams with rectangular cross-section (slabs loaded over full width). This approach may however be inconsistent, as the actual behaviour of slabs under concentrated loads affects a two-way slab response, with the shear forces not developing a parallel manner in the failure region and with potential redistribution of the internal forces for increasing levels of load.In this research, a series of 12 tests on 6 full scale slabs (3.00m x3.00m x 0.18 m) is presented. The slabs were centrally supported on an aluminium profile and were subjected to two concentrated symmetrical loads. J.Sagaseta et.al, (2014) investigated the structural behaviour of RC flat slabs supported on rectangular interior columns and the influence of the loading conditions (one or two-way bending) on their punching shear strength. The punching shear strength of slabs at rectangular columns can be lower than at equivalent square columns with a similar length of the control perimeter. This is due to a potential concentration of shear forces along the control perimeter. Some, but not all design formulas for punching design, consider this reduction on strength using empirical factors, which are written in terms of the columns geometry only. However, in reality, the concentration of shear forces depends also on the deflected shape of the slab. It is shown in this study that this can be consistently considered by means of the shear-resisting control perimeter. A sound approaches presented to estimate the shear-resisting control perimeter. K. Micallef et.al., (2014) presented an analytical model based on the critical shear crack Theory which can be applied to flat slabs subjected to impact loading. This model is particularly useful for cases which as progressive collapse analysis and flat slab-column connections subjected to an impulsive axial load in the column. The novelty of the approach is that it considers (a) the dynamic punching shear capacity and (b) the dynamic shear demand, both in terms of the slab deformation (slab rotation). The model considers inertial effects and material strain-rate effects although it is shown that the former has a more significant effect. Moreover, the model allows a further physical understanding of the phenomena and it can be applied to different cases (slabs with and without transverse reinforcement) showing a good correlation with experiment data. Robert Koppitz et.al, (2014) performed an experimental study of full-scale reinforced concrete flat slabs crosswise strengthened with prestressed carbon fibre-reinforced polymer (CFR)) straps against punching shear. The effects of two strap anchoring system and of slab thickness on punching behaviour were compared. In one system the anchors were adhesively bonded to the concrete surface, while an external steel frame balanced the horizontal strap force components in the second system. Pinho Ramos et.al, (2014) presented the experimental analysis of flat slab specimens with tendons under punching. Nine slabs were tested using unbounded prestress with high strength steel tendons. The influences on the punching capacity of the vertical component of the prestress forces resulting from inclined tendons near the column and their distance to the column are analysed. The in-plane compression force due to prestress was not applied to the slabs, in order to evaluate only the deviation force influence. The work aims to improve the understanding of the behaviour of prestressed flat slab under punching load in order to properly evaluate the punching resistance of these kind structures. The experimental punching loads are compared with the provision of EC2, ACI 318-11 and MC2010. Kwang-SooYoum et.al.,(2014) presented the punching shear resisting capacity of lightweight aggregate concrete (LWAC) slabs having low reinforcement ratio. Five full scale slabs were constructed using normal concrete and four different types of LWAC. The experimental study was then performed to study the effect of LWAC on the punching shear resisting capacity of slabs. The nonlinear finite element analysis was also conducted for each slab specimen to analyse the failure mechanism of LWAC slabs with low reinforcement ratio, by demonstrating the cracks formation and propagation. Finally from the test results of this study and previous researches, a simple design equation to predict the punching shear resisting capacity of LWAC slabs was proposed considering the reinforcement ratio of the slab. The proposed equations provided good prediction of the punching shear resisting capacity of LWAC slabs with different reinforcement ratios. M.Hasan Meisami et.al, (2014) tested the two-way flat slabs with central punching shear loading. All the slabs were designed according to ACI 318-08 Code provisions. One slab served as control without any modification while three slabs were strengthened in different ways with innovative techniques of using FRP fans after casting to increase shear capacity and provide sufficient anchorage. For strengthening in each case, 8, 16 and 24 strengtheners were used. The results of the experiments showed that the presented strengthening method is capable of enhancing both maximum loading capacity and deformation capacity as well as avoiding brittle failures that may occur under vertical loading. Duarte M.V.Faria et.al., (2014) proposed a technique for strengthening against punching shear is investigated on the basis of the physical model proposed by the critical Shear Crack Theory (CSCT). This approach allows taking into account the amount, layer and mechanical behaviour of the bonded FRP's in a consistent manner to estimate the lunching strength and deformation capacity of strengthened slabs. The approach is first used to predict the punching strength of available test data, showing a good agreement. Robert Koppitz et.al, (2014) studied the load deformation behaviour of flat slab under punching shear. Punching shear resistance usually constitutes the decisive design criterion for reinforced concrete flat slabs supported by columns. Modelling approaches based on Kinnunen and Nylander's rotation-symmetric sector mode, such as the Quadrilinear sector Model (QSM), allow the prediction of the slabs load rotation behaviour. Robbert Koppitz et.al., (2014) performed an experimental study of full-scale reinforced concrete flat slabs crosswise strengthened with prestressed carbon fibre-reinforced polymer (CFRP) straps against punching shear. The effects of two strap anchoring systems and of slab thickness on punching behaviour were compared. In one system the anchors were adhesively bonded to the concrete surface, while an external steel frame balanced the horizontal strap force components in the second system. Strap activation and thus strap force increments were higher in cases with either lower prestressing or higher strap stiffness. Nuno D.Gouveia et.al, (2014) presented the experimental study of the behaviour of SFRC flat slabs up to failure under a concentrated loading. Accompanied by the study of the mechanical properties of the SFRC, which consisted in three-point loading notched beams, compression and splitting tests. In their study, the hooked end steel fibre dosages varied between 0% and 1.25% by volume. Test results showed that the inclusion of steel; fibres influences both slab stiffness and its load capacity. Increments of load capacity up to 64% were obtained in slabs with SFRC compared with the reference slab without fibres. The experimental results were compared with the predictions provided by several existing models. Sang Whan Han and Chang seok Lee (2014) evaluated the punching shear strength of voided transfer slabs by conducting experimental tests on five transfer slab specimens. Based on the test results, methods were developed for accurately calculating the punching shear strength of voided transfer slabs. Thomas Jaeger (2014) presented the description of the shear strength of orthogonally reinforced concrete slabs with transverse reinforcement by the newly developed extended sandwich model. Based on a sandwich model, the slab element is subdivided into two cover elements and a core element. The applied in-plane forces on the cover elements are treated with the cracked membrane model. Regarding shear transfer, rotating crack faces that are able to transfer shear stressed by aggregate interlock are assumed in the core, whereas the crack orientation relative to the slab plane is determined by the crack pattern of the covers. The influences of a deviation of the principal shear and moment direction from the direction of the in-plane reinforcement as well as the transverse reinforcement ratio on the shear strength and the deformation capacity are demonstrated. Mohammed Hassan et.al, (2014) proposed the design equation to predict the punching-shear resistance of two-way concrete slabs reinforced with FRP bars and stirrups. The proposed equation is based on adopting the concrete contribution equation from the CSA S806-12 and modifying the stirrup contribution equation of the CSA A23.3.-04 to reflect using FRP materials instead of steel. The proposed modification was verified against the test results of an extensive experimental work conducted on full-scale-two-way specimens measuring 2500mm x 2500 mm x 200 mm or 350mm. The accuracy of the predictions was compared to the test results. The results of this study supported the strain limit of 4000 micro strains in the FRP stirrups for calculating the contribution of the FRP stirrups to the punching –shear capacity, as provided by ACI 440 Committee and CSA S6S1-10. Thibault Clement et.al.,(2014) presented the results of tests on 15 slabs (3000 x 3000 x250 mm ) tested to failure under different loading conditions. The aim of the tests was to investigate in a separate manner the different actions induced by prestressing on the punching shear strength (in-plane forces, bending moments and bonded tendons) These results are finally investigated on the basis of the physical model of the Critical Shear Crack Theory.

J.M.Russell et.al, (2015) investigated experimentally the dynamic response of reinforced concrete flat slabs after a sudden column loss. Seven 1/3 scale reinforced concrete flat slabs were tested under static load increased or dynamic column removal cases with different supports removed. Reaction forces and deflections were recorded throughout, along with reinforcement strains and concrete cracking patterns. During dynamic tests, a high speed camera was used to capture the dynamic motion. The experiments demonstrated that flat slabs, in general, are able to redistribute their loading effectively after a column loss. Arja Saarenheimo et.al, (2015) conducted experimental study on reinforced concrete slabs under impact loading. A shear punching test series is being carried by using as a target a two way simply supported concrete plate with a span of 2m, and a thickness of 25 cm. The mass of the impacting stainless steel missile-type projectile is 50 kg.The capabilities of different types of calculation methods in assessing local shear deformation and possible shear punching cone formation are studied. Amir H.Gandomi and David A.Roke (2015) examined the performances of two well-known soft computing predictive techniques, artificial neural network (ANN) and genetic programming (GP), are evaluated based on several criteria, including over-fitting potential. A case study in punching shear prediction of RC slabs is modelled here using a hybrid ANN (which includes simulated annealing and multi-layer perception) and an established GP variant called gene expression programming. The ANN and GP results are compared to values determined form several design codes. Adam Wosatko et.al.,(2015) presented numerical simulations of punching shear in a reinforced concrete slab-column configuration formerly tested in the laboratory. For the simulation, a symmetric quarter of the test configuration is employed.Full three-dimensional finite element discretized geometry is considered together with elastic –plastic reinforcement embedded as truss elements in concrete. Two regularized numerical models of concrete, formulated within elastic –plastic-damage theories, are applied. Joaquim A.O. Barros et.al., (2015) discussed experimental assessment of the effectiveness of steel fibre reinforcement in terms of punching resistance of centrically loaded flat slabs and to the development of an analytical model capable of predicting the punching behaviour of this type of structures. For this, eight slabs of 2550 x 2550 x150mm dimensions were tested up to failure, by investigating the influence of the content of steel fibres (0, 60, 75 and 90 kg/m3) and concrete strength class (50 and 70 MPa).Two reference slabs without fibre reinforcement, one for each concrete strength class, and one slab for each fibre content and each strength class compose the experimental program. The results have revealed that steel fibres are very effective in converting brittle punching failure into ductile flexural failure, by increasing both the ultimate load and deflection, as long as adequate fibre reinforcement is assured. Robert Koppitz et.al, (2015) conducted the experimental study on flat slabs to evaluate the punching shear with different load histories. The unloading of reinforced concrete slabs results in residual slab rotations and reloading to the same load results in irreversible rotation increases. Unloading and reloading (UR) cycles applied to non-strengthened and strengthened flat slabs may thus affect the punching resistance, which is rotation-dependent. A quintilinear moment-curvature relationship, which takes concrete softening and tension stiffening into account, combined with UR cycles, modelled as bilinear envelopes is developed to predict residual slab rotations and irreversible rotation increases. Eva O.L.Lantsoght et.al, (2015 investigated the influence on the shear capacity of using plain reinforcement bars and of supporting the slab by discrete bearings. To study these parameters and their influence on the shear capacity, a series of experiments was carried out on continuous one-way slabs (5m x 2.5m x 0.3 m), subjected to concentrated loads close to the support line. The results from these experiments are compared to code provisions and a method developed by Regan. These experiments confirm the findings that slabs subjected to concentrated loads close to supports have larger shear capacities than beams. Ashraf Mohamed Mahmoud (2015) a parametric study was carried out to look at the variables that can mainly affect the mechanical behaviours of the model such as the change of loading types and positions and slab with openings. Good correlation is observed between the results of the proposed model and other experimental one, resulting in its capability of capturing the fracture of flat slab under punching shear behaviour to an acceptable accuracy. G.Campione et.al.,(2015) discussed a simplified model for hand verification of the flexural and shear strength of existing corroded T beams cast in place of lightened R.C.orthotropic slabs forming floors. Diffused and pitting corrosion on steel bars, compressive concrete strength degradation and concrete bond strength degradation are included in the model. The original contribution of the work is evaluation of the flexural and shears strength considering both the cases of strain compatibility and absence of compatibility and considering the main parameters governing the corrosion process. Jurgen Einpaul et.al, (2015) presented an axisymmetric numerical model that allows analysing the role and significance of these effects on the flexural deformations of continuous flat slabs. Combined with the failure criterion of the Critical shear crack Theory, this model used to predict the punching capacities of such slabs. Comparisons are made to the results of some unconventional punching tests from the literature showing sound agreement between the modelling results and the experimental observations. The results suggest that the punching capacity of continuous slabs with low amounts of flexural reinforcement in the interior column regions may be underestimate in the current codes of practice. NebojsaOrbovic et.al., (2015) conducted the work related to the influence of transverse reinforcement on perforation capacity of reinforced concrete (RC) slabs under “hard” missile impact (impact with negligible missile deformations). The study presents the results of three tests on reinforced concrete slabs conducted at VTT Technical Research Centre (Finland), along with the numerical simulations as well as a discussion of the current code provisions related to impactive loading. Marcos D.E.Teixeria et.al, (2015) presented the numerical simulations for the punching behaviour of centrally loaded steel fibre reinforced self-compacting concrete (SFRSCC) flat slabs. Eight half scaled slabs reinforced with different content of hooked-end steel fibres (0.60, 75 and 90 $kg/m^3$) and concrete strengths of 50 and 70 MPa were tested and numerically modelled. Moreover, a total of 54 three- point bending tests were carried out to assess the post-cracking flexural tensile strength. All the slabs had a relatively high conventional flexural reinforcement in order to promote the occurrence of punching failure mode. Neither of the slabs had any type of specific shear reinforcement rather than the contribution for the steel fibres. The numerical simulations were performed according to the Reissner-Mindlin theory under the finite element method framework. Regarding the classic formulation of the Ressner-Mindlin theory, in order to simulate the progressive damage induced by cracking, the shell element is discretized into layers, being assumed a plane stress state in each layer. The numerical results are, then, compared with the experimental ones and it is possible to notice that they accurately predict the experimental force-deflection relationship. The type of failure observed experimentally was also predicted in the numerical simulations. Nuno Reis et.al., (2015) carried out numerical and analytical investigations about the effects of incorporating coarse recycled concrete aggregates (CRCA) on the punching behaviour of reinforced concrete (RC) slabs. For this purpose, four concrete mixes were designed with various substitution ratios of natural coarse aggregates (NCA) by CRCA: 0% (reference mix), 20%, 50% and 100%.Subsequently,eight 1100 x 1100 x 90mm reinforced concrete slabs (two per concrete type) were cast and subjected to punching tests. The experimental results indicate that the incorporation of CRCA affects the mechanical behaviour of RC slabs according the following trends: (i) the punching resistance of slabs made of concrete with CRCA (CRCAC) is similar to that of the reference mix; (ii) the stiffness decreases, particularly in the uncracked state; and (iii) the cracking load slightly decreases. The numerical study comprised the development of three-dimensional non-linear finite element models of the slabs. The numerical models were able to trace the experimental responses of the slabs tested, highlighting the influence of the concrete fracture energy on the numerical results. The best predictions of punching strength were obtained when similar fracture energy was adopted for all concrete mixes. Finally, the accuracy of some of the most relevant design codes in predicting the punching strength of CRCAC slabs is assessed. The most accurate estimates were obtained using Model Code 20120 (MC2010) with levels of approximation II to IV. Eurocode 2.AcI 318 and MC 2010 with level of approximation I provided less accurate and relatively conservative punching strength predictions. Hazem M.F.Elbakry and Said M.Allam (2015) presented an experimental and analytical study on the punching strengthening of reinforced concrete two-way slabs using external steel plates. Five reinforced concrete square slabs of 100mm thickness were tested over simply supported four sides of 1000mm span under central square patch load of 100 mm sized up to failure One control slab was tested without strengthening; however, four tested slabs were strengthened using four configurations of square steel plates provided with steel anchor shear studs. Such configurations considered two different plate thickness, two plate side dimensions and different arrangement and diameter of shear studs. The strengthened four slabs showed improved stiffness and punching shear capacity. The magnitude of improvement depended on the plate dimensions and the studs diameter and arrangement. An analytical approach was proposed for predicting the punching shear strength increase due to using the strengthening steel plate. The proposed approach was applied to the tested specimens with the use of the punching shear strength equations adopted by several codes of practice and proved to be in good agreement with test results. M.Fernandez Ruiz et.al., (2015) reviewed the various potential shears – transfer actions in reinforced concrete beams with rectangular cross-section and discusses on their role, governing parameters and the influences that the size and level of deformation may exhibit on them. This is performed by means of an analytical integration of the stresses developed at the critical shear crack and accounting for the member kinematics. The results according to this analysis are discussed, leading to a number of conclusions. Finally, the resulting shear strength criteria are compared and related to the Critical shear crack theory. This comparison shows the latter to be physically consistent, accounting for the governing mechanical parameters and leading to a smooth transition between limit analysis and Linear Elastic Fracture Mechanics in agreement to the size-effect law. M.Hasan Meisami et.al, (2015) carried an experimental program on two-way flat slabs with central loading. All the slabs were designed according to ACI 318-08 code provisions. One slab served as control without any modification while three slabs were strengthened in different ways with an innovative technique of using FRP fans after casting to increase shear capacity and provide sufficient anchorage. For strengthening in each case, 8, 16 and 24 strengtheners were used. The results of the experiments shown that the presented strengthening method is capable of enhancing both maximum loading capacity and deformation capacity as well as avoiding brittle failures that may occur under vertical loading capacity and deformation capacity as well as avoiding brittle failures that may occur under vertical loading. The dominant failure mode for flat slabs strengthened with FRP fans was deboning of FRP fans due to the small depth of slabs and simultaneously with separation of end anchorage from the concrete surface. It was shown that this method of strengthening not only can increase the shear capacity of the slab up to a high value around twice of that of controlled slab but also may change the slab failure mode from shear to shear-flexural and also flexural. Hamed S.Askar (2015) presented a system for repairing damaged flat plates as a result of punching shear. The system depends mainly on repairing the damaged concrete and the addition of vertical studs with different arrangements through holes drilled in the plates. The Experimental program consists of eight specimens with the same dimensions and flexural reinforcements, but with different concrete strength and shear reinforcement ratios. The main aim of the tests is to assess the efficiency of the suggested repairing system and to investigate the slabs load carrying capacity, deformation characteristics and cracking behaviour. Test results showed that using the proposed system on repairing damaged flat plates due to punching shear is very efficient. Theoretical results obtained based on the formulas adopted by different codes and from the critical shear crack theory (CSCT), showed a satisfactory agreement with test results. Joaquim A.O. Barros et.al., (2015) carried the experimental assessment of the effectiveness of steel fibre reinforcement in terms of punching resistance of centrically loaded flat slabs, and to the development of an analytical model capable of predicting the punching behaviour. For this purpose, eight slabs of 2550 x 2550 x 150 mm dimensions were tested up to failure, by investigating the influence of the content of steel fibres (0, 60, 75 and 90 kg/m3) and concrete strength class (50 and 70 MPa).Two reference slabs without fibre reinforcement, one for each concrete strength class, and one slab for each fibre content and each strength class compose the experimental program. All slabs were flexurally reinforced with a grid of ribbed steel bars in a percentage to assure punching failure mode for the reference slabs. Hooked ends steel fibres provided the unique shear reinforcement. The results have revealed that steel fibres are very effective in converting brittle punching failure into ductile flexural failure, by increasing both the ultimate load and deflection, as long as adequate fibre reinforcement is assured. An analytical model was developed based on the most recent concepts proposed by the fib Mode Code 2010 for predicting the punching resistance of flat slabs and for the characterization of the behaviour of fibre reinforced concrete. The most refined version of this model was capable of predicting the punching resistance of the tested slabs with excellent accuracy and coefficient of variation of about 5%. Hamed S Askar (2015) examined the retrofitting flat slabs, damaged due to punching shear using prestressed with vertical bolts. The parameters examined in this study are vertical prestressed bolts with different ratios within the slab thickness, slab thickness and central column size. Through the experimental tests the load carrying capacity, deformation characteristics and the cracking behaviour have been investigated. A comparison between the behaviour of retrofitted slabs and their references showed that the proposed system of repair is effective and could be used in practice. A comparison between the experimental results and calculated punching failure load based on the formulas adopted by different codes, showed a reasonable agreement. Iyad Alkroosh and Hayder Ammash (2015) applied Gene Expression

Programming (GEP) approach for predicting the punching shear strength of normal and high strength reinforced concrete flat slabs. The GEP model was developed and verified using 58 case histories that involve measured punching shear strength. The modelling was carried out by dividing the data into two sets: a training set for model calibration, and a validation set for verifying the generalization capability of the model. It is shown that the model is able to learn with high accuracy the complex relationship between the punching shear and the factors affecting it and produces this knowledge in the form of a function. The results have demonstrated that the GEP model performs every well with coefficient of determination, mean, standard deviation and probability density at 50% equivalent to 0.98, 0.99, 0.10 and 0.99 respectively. Moreover, the GEP predicts punching shear strength more accurately than the traditional methods. Beatrice Belletti et.al, (2015) provided a nonlinear finite element (NLFE) approach which adopts to multi-layered shell modelling of RC slabs. FE analysis were carried out with ABAQUS code and UMAT, for user subroutine in which the crack model denoted as physical approach for Reinforced concrete for cyclic Loading (PARC.,CL) was implemented, Post-processing of NLFEA results is presented which exploits the Critical Shear Crack Theory (CSCT) to evaluate the punching shear resistance of shell elements. The capability of the proposed numerical procedure, to properly determine the punching shear resistance of RC slabs, is checked by comparing numerical predictions with experimental punching shear capacities obtained on circuit slabs tested at the Stevin Laboratory of TU Delft. Jurgen Einpaul et.al, (2015) introduced a numerical model to analysing the role and significance flexural deformations of continuous flat slabs. By considering the failure criterion of the Critical Shear Crack Theory, a model was used to predict the punching capacities of such slabs. Comparisons are made to the results of some unconventional punching tests from the literature showing sound agreement between the modelling results and the experimental observations. The results suggest that the punching capacity of continuous slabs with low amounts of flexural reinforcement in the interior column regions may be underestimated in the current codes of practice. Hazem M.F et.al., (2015) carried out a study on punching strengthening of reinforced concrete two-way slabs using external steel plates. Five reinforced concrete square slabs of 100mm thickness were tested over simply supported four sides of 1000 mm span under central square patch load of 100 mm size up to failure. One control slab was tested without strengthening; however, four tested slabs were strengthened using four configurations of square steel plates provided with steel anchor shear studs. Such configurations considered two different plate thickness, two plate side dimensions and different arrangement and diameter of shear studs. The strengthened four slabs showed improved stiffness and punching shear capacity. The magnitude of improvement depended on the plate dimensions and the studs diameter and arrangement. An analytical approach was proposed for predicting the punching shear strength increase due to using the strengthening steel plate. The proposed approach was applied to the tested specimens with the use of the punching shear strength equations adopted by several codes of practice and proved to be in good agreement with the test results. Abu N.M.Faruk et.al, (2015) proposed a simple Punching Shear Test (SPST) to evaluate and characterize the Hot mix asphalt (HMA) shear properties. The SPST protocol and the input parameters were established through a series of comprehensive trail testing of HMA mixes commonly used in Texas. SPST data analysis models were derived to evaluate various HMA shear parameters including the shear strength, shear modulus and shear strain energy (SSE).The corresponding results indicated that the SPST has promising potential to routinely differentiate and screen HMA mixes in terms of their shear resistance potentials. Aikaterini S et.al, (2015) performed a nonlinear finite element analyses to reinforced concrete slab-column connections under static and pseudo-dynamic loadings. The 3D finite element analyses (FEA) were performed with the appropriate modelling of element size and mesh, and the constitutive modelling of concrete. The material parameters of the damaged plasticity model in ABHAQUS were calibrated based on the test results of an interior slab-column connection. The predictive capability of the calibrated model was demonstrated by simulating deferent slab-column connections without shear reinforcement of interior slab-column specimens under static loading, interior specimens under static and reversed cyclic loadings, and edge specimens under static and horizontal loadings were examined. The comparison between experimental and numerical results indicates that the calibrated model properly predicts the punching shear response of the slab. Zhen-Yu Huang et.al,(2015) investigated the ultimate strength behaviour of steel-concrete steel (SCS) sandwich shell experimentally and analytically. Two pilot quasi-static tests on the lightweight SCS sandwich composite shells subject to patch loading are carried out. The failure mode of composite shell is punching shear. Tests show that the punching shear resistance depends on the control perimeter of punched concrete frustum and shear connectors. The membrane action of the outer steel plates provides post-hardening strength. On the basis of the experimental failure mechanism, an analytical model is developed to explain the force transfer mechanism and predict the punching shear resistance of SCS sandwich composite shell. The verification of the model shows that the predictions are in good agreement with the test results. Michael M.G. Inacio et.al, (2015) research carried out to study the punching behaviour of high strength concrete (HSC) flat slabs. Three flat slab specimens were cast using HSC and another one with normal strength concrete (NSC), to be used as a reference slab. The HSC mix presented a compressive strength of about 130 MPa, with a basalt coarse aggregate. The tested specimens were square with 1650mm side and 125m thickness. The longitudinal reinforcement ratio varied between 0.94% and 1.48%. The experimental results show that the use of HSC led to a significant load capacity increase when compared with the reference model made with NSC. Furthermore, the experimental results also indicate that as the longitudinal reinforcement ratio increased, the punching capacity also increased. The results obtained in this set of experimental tests and others collected from the literature were compared with the code provisions by EC2, MC2010 and ACI 318-11. A.M.T.Hassan et.al, (2015) made an attempts to design a novel testing method to measure the punching shear capacity of the concrete. The designed test arrangement was employed to carry out an extensive experimental study on Ultra High performance Fibre reinforced concrete (UHPFRC) slabs subjected to punching shear failure. From the results obtained, the relationship between the punching shear load and the angle of the shear plane, the critical value of the basic control perimeter and failure mode were studied. The experimental study undertaken here provides significant insight into the punching shear capacity of UHPFRC slabs. The results illustrate and high light many of the advantages of using UHPFRC compared to normal concrete in structural designs. The novel punching shear test presented here has established itself as a suitable procedure for testing UHPFRC and potentially other fibre reinforced composites. Robert Koppitz et.al, (2015) performed a parametric study on the effect of unloading and reloading (UR) cycles on the punching resistance of concrete is normally small. However, it may be significant if the slab is strengthened after unloading, particularly for thin and low-reinforced slabs, which exhibited plastic slab rotations before unloading. Presenting of the strengthening system may reduce the residual slab rotations and thus limit or compensate the loss of punching resistance. Ashraf Mohamed (2015) carried a parametric study to look at the variables that can mainly affect the mechanical behaviours of the model such as the change of loading tyres and positions and slab with openings. Good correlation is observed between the results of the proposed model and other experimental one, resulting in its capability of capturing the fracture of flat slab under punching shear behaviour to an acceptable accuracy. M.Fernandez Ruiz et.al., (2015) reviewed the various potential shear transfer actions in reinforced concrete beams with rectangular cross-section and discusses on their role, governing parameters and the influences that the size and level of deformation may exhibit on them. This is performed by means of an analytical in integration of the stresses developed at the critical shear crack and accounting for the member kinematics. The results according to this analysis are discussed, leading to a number of conclusions. Finally, the resulting shear strength criteria are compared and related to the Critical Shear Crack Theory. This comparison show the latter to be physically consistent, accounting for the governing mechanical parameters and leading to a smooth transition between limit analysis and Linear Elastic Fracture Mechanics in agreement to the size-effect law provided by earlier researcher. Ahmed Ibrahim et.al., (2015) proposed a new alternative of reinforcement, the introduction of rebar mesh at the middle of flat plate thickness covering the punching zone and anchored outside this zone. Nevertheless, in their investigation, the proposed reinforcement system is examined for interior columns only. An experimental work consisting of eight specimens, of normal and high strength concrete, and an expanded analytical work using the finite element method had been carried out in order to investigate the effect of this additional reinforcement for both normal strength and high strength concrete. The computer program ANSYS-V12.0 has been utilized in the finite element analysis. The obtained results indicate that, the proposed shear reinforcement system has a positive effect in the enhancement of both the punching shear capacity and the strain energy of interior slab-column connection of both normal and high strength concrete. The general finite element software ANSYS can be used successfully to simulate the punching shear behaviour of reinforced concrete flat plates. Joaquim A.O. Barros et.al, (2015) presented a new type of carbon-fibre-reinforced-polymer (CFRP) laminate of U-shape is used by adopting a novel hybrid technique for the simultaneous flexural and punching strengthening of existing RC slabs. Besides, this hybrid technique aims to provide a better bond performance for the embedded-through-section (ETS) and near-surface mounted (NSM) CFRPs by improving the anchorage conditions.Moreover,a higher resistance to the susceptibility of occurrence of other premature failure modes, like concrete cover delamination, is offered by using this hybrid technique. A 3D nonlinear finite-element (FR) model is developed to simulate the experimental tests by considering the nonlinear behaviour of the constituent materials. The experimental program and numerical model are described, and the relevant results are analysed. Francisco Natario et.al, (2015) investigated the behaviour of cantilever bridge deck slabs under fatigue loads. A specific experimental programme consisting on eleven tests under concentrated fatigue loads and four static tests (reference specimens) is presented. The results show that cantilever bridge deck slabs are significantly less sensitive to shear –fatigue failures than beams without shear reinforcement. Some slabs failed due to rebar fractures. They presented significant remaining life after first rebar failure occurred and eventually failed due to shear. The test results are finally compared to the shear-fatigue provisions for the fib-Model Code 2010 and the critical shear crack theory to discuss their suitability.

J.Daniel Ronald Joseph et.al., (2016) conducted experimental and analytical studies carried out to understand and compare flexural behaviour of concrete sandwich panels under two different loading conditions such as punching and four –point bending are presented and discussed. Experimental study indicates that, type of loading conditions affects the flexural behaviour of the concrete sandwich panels significantly. The panel subjected to punching load failed in flexural mode, and its behaviour is similar to conventional RC slab. Under four-point bending the panel failure is attributed to failure of concrete by combined effect of shear and flexural stresses. For both types of loading conditions, analytically predicted cracking moment is comparable to the experimental cracking moment. Further experimental and analytical studies are required in this area to develop design guidelines for practical applications of these types of panels under different loading conditions. Fathi Abdrabbo et.al.,(2016) showed the performance of shear span to depth ratio of a footing and distributions of contact stress at footing-soil interface and also noticed that they are key factors in the structural design of the footing. ECP203-11, AC1318-08, and EC2-2004 code provisions are tested for this study and it is noticed as the code provisions underestimate the structural failure loads of isolated column footings, while BHS 8110.12-1997 over predicts the failure loads of isolated column footings, if punching provisions at perimeter of column are pulled out from the code. Andre F.O.Almeida et.al, (2016) studied the behaviour of reinforced concrete flab slab structures under combined vertical and horizontal cyclic loading. A total of five specimens were cast and tested: a control specimen was, punched without eccentricity, one specimen was tested under constant vertical loading and monotonically increased eccentricity until failure and the remaining three were tested under constant vertical load, at different shear ratios, and cyclic horizontal loading with increasing horizontal drift ratios. All slabs were similar, measuring 4.25X1.85x0.15m.The reinforced concrete slab specimens were connected to two steel half columns by 0.25 x 0.25 m rigid steel plates, prestressed against the slab using steel bolts, to ensure monolithic behaviour. The cyclic tests were performed using an innovative test setup that allows bending moment redistribution, line of inflection mobility, assures equal vertical displacement at the North-South borders and symmetrical shear forces. Results show that cyclic horizontal actions are very harmful to the slab-column connection, resulting in low horizontal drifts and energy dissipation. M.A.Baril et.al.,(2016) conducted experimentally investigation on the effect fibre orientation and the damage behaviour of high performance Fibre reinforced concrete (HPFRC) two way thin slabs by means of stereovision digital image analysis. To this aim, the fibre orientation was perturbed by introducing a simple divider line as a temporary barrier to the casting flow of fresh concrete. The casting flow defect affected the fibre distribution by creating a weakened plane with a strong discontinuity. By varying the line direction and the position of the concentrated load position, six different slab configurations were fabricated and tested under punching load with hyper static boundary conditions. Then, the 3-D deformation field was measured by means of stereovision based Digital image correlation (DIC).The results showed the critical importance of the fibre distribution on the micro cracking growth and the structural ductility. The casting flow defect had a major impact on the observed micro crack pattern and growth especially before the peak load. When the defect crossed the loading point, the micro cracks did not fully develop with an important reduction of the load-carrying capacity and the structural ductility. Finally, a simplified application of yield line theory allowed estimating the effect on the fibre distribution of the casing flow defects. Malena Bastien-Masse and Eugen Bruhwiler (2016) proposed an analytical composite model to predict the global bending behaviour of the composite slab and the punching shear resistance. A multilinear moment-curvature relation for composite sections is proposed to calculate the global force-rotation behaviour of a slab which can then be used in combination with a composite failure criterion to predict the punching shear resistance. The contribution of the concrete section to the punching shear resistance is obtained with existing models from the literature. The Ultra-High performance Fibre reinforced cement-based Composite (UHPFRC) layer resists to punching shear by out-of-plane bending over a limited length equal to its height. This mechanism induces tensile stresses perpendicularly to the interface with the concrete. The contribution of the UHPFRC layer of the punching shear resistance thus depends on the tensile strength of concrete. The results of this analytical composite model are in good agreement with the experimental result. A method is also proposed to consider pre-existing deformation of the Reinforced concrete (RC) section for a post-installed UHPFRC layer. D.V. Bompa and A.Y. Elghazouli (2016) investigated the structural performance of hybrid members consisting of reinforced concrete flat slabs, with and without shear reinforcement, connected to steel columns by means of fully integrated shear-heads. A detailed account of the results from a series of six large scale tests on this form of hybrid structural system is provided. The test results offer a direct evaluation of the full load-deformation behaviour of the specimens as well as the ultimate punching shear strength attained prior to failure at the critical slab perimeter outside the shear –heads region. The experimental findings enable the development of analytical models that depict the rotational response and flexural strength as a function of the shear-head embedment length, layout and section size, additionally, the test results support the definition of a shear-head dependent control perimeter which is used in conjunction with the analytical slab models for full assessment of punching shear strength. The adequacy of strength predictions incorporated in design methods for conventional reinforced concrete members are also examined in the paper. It is shown that existing design procedures either lack direct guidance for members provided with shear heads, or lead to overly conservative strength predictions. Finally, in order to provide a reliable evaluation of the ultimate punching shear strength of hybrid elements, analytical design expressions which account for the characteristics of the shear-head system, are proposed. In comparison with conventional reinforced concrete design provision, the suggested approach captures in a more realistic manner the influence of the embedded length of the shear-heads for such hybrid members with or without shear reinforcement. Angelo Carfatelli et.al.,(2016) were investigated the effect of light weight fibre reinforce material on the punching shear resistance.Furthermore,ashes coming from the combustion of Municipal solid waste (MSW) with pozzolanic reaction were added to the concrete mix. The obtained results are presented, discussed and compared with the MC2010 provision. T.T.Bui et.al, (2016) analysed the shear behaviour of full-scale slabs without shear reinforcement under a concentrated load near a linear support. Experimental tests were conducted to quantify the shear strength and the associated failure modes. The work addressed the influence of several variables, such as bottom longitudinal reinforcement, bottom transverse reinforcement, compressive strength, concrete aggregate size, and influence of the slab depth. A series of ten sets of nine full-scale slabs (one slab of 3.2 m X 2.9m X 0.3 m; six slabs of 4m X 2.6m X 0.3m; one slab of 4m X 2.6m X 0.35m; one slab of 4m X 2.6 m X 0.4 m) are presented. Realistic boundary conditions with the slabs supported on all four sides were used. The experiments are firstly used to evaluate the pertinence of Eurocode for the shear design of reinforced concrete slabs without shear reinforcement in comparison with the French approach, and then to make comparisons with the ACI 318-14 code. Thai X et.al, (2016) conducted experimental study to evaluate the effectiveness of Shear stud layouts in slab-column connections whose slabs have relatively low flexural reinforcement ratios. Three full-scale slab-column connections that represent a flat place structure with 7.62m span were tested. All three specimens have identical flexural design, in which the reinforcement ratio was 0.8%. One specimen was built without shear reinforcement, and the remaining two specimens were reinforced with shear studs in either a radial or orthogonal layout. For the specimens with shear studs, calculated shear strengths were higher than their estimated flexural strengths.

## III. CLOSURE

From the above review, it came to know that the punching shear criterion is most important for slab elements. Many works are taken up with full scale models and from them it is observed that, the strength and stiffness are varying with effect of reinforcement (Steel, CFRP, and GFRP) provision and incorporation various fibres. Some works are taken up with shear studs to strengthen of shear capacity of slabs. Few works are focused with cyclic loading along with static loads. The models are checked with different cods of ACE, Euro code and MC 210 codes. Some works are also tested with Finite Element Analysis and few researchers are focused the punching shear behaviour on precast elements. The author would like to express to the reader, still innovative method are there to strengthen the shear capacity for slab elements using na-no materials and crack analysis can be analysed with advanced technology of Digital Image Processing.

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