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Punching Shear of Reinforced Geopolymer Concrete Slabs with and without Openings: A Review

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***Abstract*:- This paper presents a review summery to know about the eco-friendly concrete namely as geopolymer concrete and its behaviour in fibre reinforced concrete slabs with and without openings under punching shear. One of the critical variables influencing the punching shear strength of the plate and determining its thickness in the area of the slab-column joint is opening in RC flat plates. The opening position may be either in the slab's positive or negative moment region, creating different issues that cannot be resolved using the same strategy. Several studies were performed to understand the behaviour of punching shear resistance of flat plates near openings.**

Key words:- Geopolymer concrete slabs, punching shear, openings in slabs, fibre reinforced concrete

1. INTRODUCTION

Flat slab system has been used for many constructions. In this system, compared to other types of structural systems, the construction period can be reduced by efficient formwork. This system can also minimize the ceiling height, which can reduce the total height of the building and further reduce the corresponding cost of the material. On the other side, flat plates cause structural issues; one of the primary practical issues is often to provide the strength at the slab-column links against a punching shear failure. This is due to the elevated shear stress associated with supporting columns, causing failure owing to punching shear at loads well below the flexural ability. Using a bigger column diameter, a greater efficient depth, more flexural reinforcement, greater concrete compressive strength or extra shear reinforcement, the punching shear capability can be improved. Fibre Reinforced Concrete is a form of concrete containing a distinct range of fibrous substances that enhance its structural strength and cohesion. Because concrete is a pretty brittle material with very excellent compressive strength but relatively low tensile strength; it can crack under many circumstances. Adding fibres will not only increase the strength ability and structural integrity, but also radically enhance the post-crack state.

This paper will be provided a review of the behaviour of reinforced concrete slabs under punching shear. Literature review will be split into two parts; the first section addresses the definition of both geopolymer concrete, concrete strengthened with steel fibre, and shear punching. The second section provides a review of the state-of - the-art studies about the punching shear behaviour of strengthened geopolymer and ordinary portland cement concrete slabs with or without opening.

2. GEOPOLYMER CONCRETE

Pollution, which is primarily linked to cement manufacturing, is one of the issues connected with the building sector. During the manufacturing of OPC Portland cement, carbon dioxide emissions are huge as the manufacturing of one ton of Portland cement emits about one ton of CO2 into the environment **[1], [2]**. Any tone of Portland cement substituted with additional cement products such as fly ash or slag is predicted to prevent emission to the atmosphere of about one part of CO2 **[2], [3]**.Geopolymer concrete is an alternative building material with similar mechanical characteristics to OPC Portland cement concrete, composed of an alumina-silicate and an alkaline solution **[5], [6]**. Geopolymer concrete based on fly ash hardens through a method called geopolymerization. This method of hardening needs thermal activation above ambient temperatures. In 1978, Professor Joseph Davidovits launched an amorphous framework called geopolymer to the growth of a new family of mineral binders. This was a strong material class, generated by an alumina-silicate powder and an alkaline liquid response.

2.1 *Terminology*

In particular, a "geopolymer" is described as a strong and stable material composed of alumina-silicates created by activation of alkali hydroxide or / and alkali silicate **[7]**.**Davidovits [8]** suggested that an alkaline liquid could be used to respond with Silicon (Si) and Aluminum (Al) powder, fly ash, meta-kaolin and red mud to generate binders in a source material of geological origin or in by-product products such as Ground Granulated Blast Furnace Slag (GGBFS) **[9], [10], [4], [11] & [12].** These polymers ' chemical designation was based on silica-aluminates. It was selected to use the word poly (sialate), with the abbreviation for silicon-oxo-aluminate being "sialate" **[13] & [14]**.The poly (sialate) network comprises of four-fold coordination of Si4 + & Al3 + ions, sharing oxygen ions,

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ranging from amorphous to semi-crystalline **[13] & [15]**. A poly (silicate) empirical formula is provided as follows:

Mn (-(SiO2) z–AlO2) n, wH2O

Where "z" is a value between 1 and 3 depending on the response chemistry, "M" is the alkali component used; "n" is the polymerization degree and "w" is the hydration degree **[15]& [13]**.

2.1.1 Geopolymer Categories

As stated above, geopolymers are created by alkali-activating a multitude of components to generate a cement-like material, including fly ash, blast furnace slag, thermally activated clays, etc. Slag, calcined clays (metakaolin) and carbon fly ash are the three most prevalent raw binders used in geopolymerization. The binder materials are expected to contain elevated concentrations of amorphous aluminum (Al) and silicon (Si). Many distinct materials in geopolymer concrete mixes have already been explored and used as the binder **[16], [17], [18]&[19]**, including:

- Class F fly-ash (low amount of calcium)
- Class C fly-ash (high amount of calcium)
- Calcined kaolin or metakaolin
- Natural minerals containing Al and Si
- Silica fume
- Slag
- Red mud
- Albite

In the early phases, metakaolin was commonly used as the binder, but it tends to have an unviable elevated water requirement owing to its flat form **[7]**. A rounder shape of fly ash particles ensures more promising workability and low water demand.

There are presently four distinct classifications of geopolymer **[10]**, including:

- Geopolymer based on slag
- Geopolymer based on rock
- Geopolymer based on fly ash
- Geopolymer based on ferro-sialates

2.1.2 Alkali-activators

Alkaline solution is utilized to activate alumino-silicate base materials in order to obtain geopolymer paste. For the alkali-activators, several choices are adopted. Alkali metal hydroxide (sodium hydroxide), carbonate, sulfate, phosphate, and fluoride (few studies) can be used as the activators. Silicate and aluminum silicate enrich the alkaline activator species in a large degree **[21]**. Theoretically, any alkali element can be used in geopolymerization reactions; however most of the studies have focused on the effect of sodium (Na+) and potassium (K+) ions**[20, 22]**. The penetration of Al atoms into the original Si-O-Si structure represented a substantial feature of this reaction. Alumino-silicate gels (geopolymer precursors) were mostly formed. Their composition can be characterized by the formula Mn [-(Si-O)z-Al–O]n.wH2O. The C-S-H and C-A-H phases may also originate in dependence on the composition of the starting materials and the conditions of the reaction. Even secondary H2O may be formed during these (poly-condensation) reactions **[23]**. Amorphous (gel-like) or partially amorphous or crystalline substances may originate in dependence on the character of starting raw materials and on the conditions of the reaction. The concentration of the solid matter plays a substantial role in the process of alkali activation **[23]**.

2.1.2.1 Sodium hydroxide (NaOH)

The most common alkaline activator used in geopolymerization was a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) in the presence of sodium silicate or potassium silicate **[24]**. The type and concentration of alkali solution affected the dissolution of raw material. The sodium hydroxide was available in flake or pellet form. It is recommended that the alkaline liquid is prepared by mixing both the solutions together at least 24 hours prior to use **[25]**.

2.1.2.2 Potassium hydroxide (KOH)

The compressive strength of the K-containing geopolymers was generally higher than the Na counterparts because Na-containing pastes were more viscous and harder to mix. In order to reach the same compressive strength level, the amount of Na-solution must be increased by 50% as compared to the K-solution, which means that the Na-based geopolymers were less user-friendly than the K-based geopolymers **[21]**.

2.1.2.3 Sodium silicate solution (Na2SiO3)

Palomo et.al [19], concluded that the type of activator played an important role in the polymerization process. Reactions occurred at a high rate when the alkaline activator contains soluble silicate, either sodium or potassium silicate, compared to the use of only alkaline hydroxides. A study conducted by **Xu and Van Deventer [26]** showed that the addition of sodium silicate solution to the sodium hydroxide solution as the alkaline activator enhanced the reaction between the source material and the solution. **Tempest et.al [27]** state that the sodium silicate activator dissolved rapidly and began to bond base material particles.

2.1.2.4 Water/ Base material ratio

The added water remained outside of the geopolymer network, acting as a lubricating element **[28]**. While the mechanism of the polymerization was yet to be fully understood, a critical feature was that water is present only to facilitate the workability and does not become a part of the resulting geopolymer structure. In other words, water is not involved in the chemical reaction and instead is expelled during curing and the subsequent drying.

3. STEEL FIBRE REINFORCED CONCRETE (SFRC)

Fibre-reinforced concrete is the concrete with the addition of brief fibres aimed at improving this material's property. Long-term dynamic loading is basically linked to its durability. Steel fibre concrete (SFRC) was by definition a composite material made of hydraulic cement, cement water and a dispersion of steel fibres nestled in the cement matrix. The matrix, i.e. the unreinforced concrete, may consist of fine and coarse aggregate, and sometimes silica and fly ash or any other prescription for the concrete mixture. The steel fibres and the matrix are initially bonded together and interact homogeneously. The matrix began to crack when the load increases and the fibres carry the load. The mechanism subsequently relied only on the shape and size of steel fibres. Depending on the anchorage length, concrete strength and proprietary shape, some fibres may fracture and others may fall

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out. In many dimensions and shapes, the industry provides steel fibres including mild steel and high tensile steel. Also accessible were stainless steel fibres. A series of warm and cold working techniques produce the steel itself. In some cases, the steel was chopped from drawn wires and in other cases its sheet slit or ingot milled. Steel fibres were also made from extract from warm melt **[29]**.

2.1.3 Mechanism of Crack Formation and Propagation

Once the steel fibres are mixed in a rotary mixer, the fibre distribution in the concrete developed in a randomly three-dimensional direction. Nonetheless, it is confirmed that increased steel fibre volume percentage in the concrete made the distribution more even. The initial cracks in the concrete occurred when the maximum stress is obtained, if the steel fibre content was high, the resistance against the stress will also be high. Where the steel fibre content was low, the resistance is decreased and so the cracks are directed to follow the line of least resistance. For that reason, the concretes crack resistance will be controlled by the steel fibre distribution and the steel fibre amount **[30].**

4. Punching Shear

Punching shear was a flat slab phenomenon triggered by focused support responses that induce a cone-shaped perforation from the top of the slab. While punching shear failure is usually preceded by flexural failure, punching shear was unwanted in structural concrete flat slab structures due to its fragile nature, which could led to a building's gradual fall **[31]**. The design strategy for punching shear assumed that in both primary directions above the column the slab is subjected to hogging moments, which postulated that the slab was either constant or that the slab-column link was momentary resistant. So the critical factor in flat slab constructions for shear was to punch shear around the columns.

4.1 Punching Shear Failure Analysis

Because of its sudden and fragile nature, punching shear failure is acknowledged as a significant danger to flat slab structures **[32]**. Many researchers have therefore regarded feasible modeling methods for determining shear forces and ability **[33] & [34]**. A latest parametric study **[35]** of punching shear in plates confirmed that the shear capability can be adequately predicted by a nonlinear 3D FEA using"8-node brick components." They found, as anticipated, that growing reinforcement ratios, concrete strength, slab thickness or column size improves ability, although more fragile failures may also result. Furthermore, comparisons have been produced between distinct shear reinforcement technologies and reinforcement methods, such as the job by **[36] & [37]**. **Fig. 1**, can provide additional shear ability via dowel action.

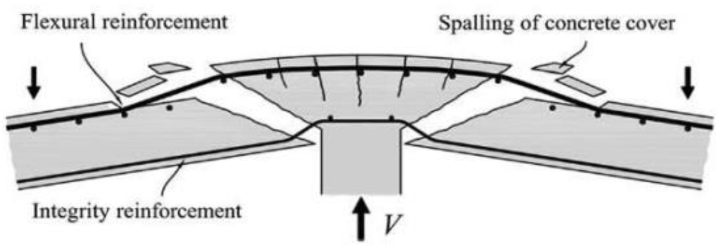

Fig.1 Flat slab failing to punch shear with reinforcement of integrity [38]

4.1.1 Failure Mechanisms

This passage will explore symmetric and unsymmetrical punching processes. Symmetrical punching happens when the load is applied to the critical section of the slab without eccentricity When, owing to wind or earthquake, flat slab buildings are subjected to horizontal loading, there is a significant unbalanced time to be transmitted at each connection. Unbalanced moment transfer creates non-uniform distribution of shear stress around the column. This reduces the shear strength of the connections. The shear force and unbalanced moment are transmitted on the faces of the critical section in the slab around the column by combining bending, torsion and shear. **Fig.2** shows typical punching shear failure and crack patterns of symmetrical and unsymmetrical punching. In flat slabs, two types of shear failure mechanisms may be encountered. The first is, beam action or one-way shear as shown in **Fig.3a**. The slab fails as a broad beam in this situation (diagonal crack forming across the slab's complete width). One-way shear stresses only need to be resisted by concrete strength and without any contribution to reinforcement. The second is shear punching or shear failure in two ways that happens around the column (focused load). The failure is triggered by diagonal stress fracture in the form of a truncated cone around the column as seen usually in **Fig.3b** the stresses arising from the two-way shear are much greater than the stresses arising from the one-way shear.

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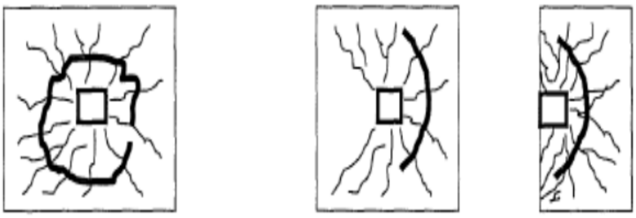
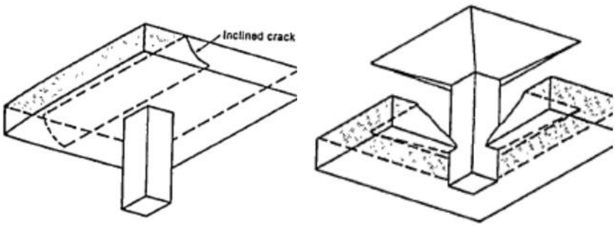


Shear only Moment and shear

Fig.2: Typical punching shear failure and crack patterns



a- One a way shear b- Two-way shear (punching)

Fig.3: Shear failure mechanisms

4.1.2 Modes of Failure for Slabs

There are three kinds of slab failure modes. These classifications depend on whether strengthening (flexure), concrete crushing or inner diagonal cracking (shear punching) or a mixture of both (flexural punching) initiated failure.

4.1.2.1 Pure flexural failure

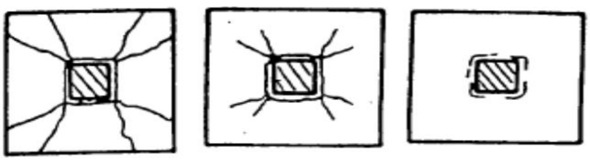
A small amount of big flexural cracks grow before failure for plates which fail in flexural mode. As shown in **Fig.4a**, the crack pattern could approach the complete yield line pattern. In slabs with a small quantity of reinforcement, this sort of failure often happens. The slab fails in a ductile mode with big deflection developing before failure, and flexural reinforcement yields spreads on a broad region of the slab at failure before final failure and yielding.

4.1.2.2 Flexural punching failure

This sort of failure, as shown in **Fig.4b**, is somewhere between pure flexural failure and pure punching failure. Yield line pattern is not fully created and punching followed by steel yield is the ultimate failure. Reinforcement yielding occurs only locally around the column.

4.1.2.3 Pure punching failure

A big amount of flexural cracks (radial and tangential) grow prior to failure but without the yield of reinforcement for plates that fail in shear mode. In strongly strengthened slab, this sort of failure often happens. The big quantity of reinforcement will significantly improve the slab's flexural ability. Because of the large bending compression plus the vertical load applied, the slab is more likely to fail in concrete crushing than in flexural steel. Finally, in the form of truncated cone, the plate fails in a local region around the column. For slabs with big quantities of shear reinforcement or small column size, as shown in **Fig.4c**, the slab may fail in local compression failure. In nature, this form of failure is fragile and occurs with small deflection.



a- Full yield line pattern b- Partial yield failure c- Compression failure

Fig.4: Modes of failure

4.1.3 Factors Influencing Punching Shear Strength

Many scientists have recognized many of the variables affecting the punching shear strength. You can summarize these parameters as:

1. Concrete strength, one of the main variables affecting the punching shear resistance is the concrete fracture energy.

2. The ratio and arrangement of reinforcing steel, the increase in the reinforcement ratio results in a greater punching shear strength while the structure's ductility is reduced.

3. Shear reinforcement, multiple kinds of shear reinforcement such as stirrups, shear studs, bent-up bars, hooked bars and welded-wire fabric were used to reduce punching. As anticipated, shear reinforcement was discovered to be efficient in boosting both shear strength and ductility.

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4. Size impact is one of fracture mechanics ' primary elements.
5. Other variables, such as type and region of loading, column shape and size as well as slab thickness, also affect the punching shear strength to varying degrees.

4.1.4 Punching Shear Calculation

One of the most commonly used techniques of assessment are based on summing up the stresses of vertical shear and the stresses of unbalanced times. The ACI 318-08 and ECP 203-2007 adopt a thorough assessment. However, the computational time needed for such assessment is still expensive and is not appropriate for computations of routine design. ACI and ECP suppose that the shear failure plane has a slab surface inclination angle of 45 degrees. The critical section for punching shear is at (d/2) from the column's face for both design methods. **Fig.5** demonstrates several examples of punching stress distribution for inner and external columns owing to an unbalanced time and critical punching shear sections.

4.1.4.1 Punching shear in ECP 203-2007

The **ECP 203-2007[41]** provides a streamlined design method to calculate the complete punching shear stress including shear stress owing to the time in some cases being moved to columns. The shear stress due to vertical gravitational loads is magnified by the factor β in this streamlined technique to account for the portion of unbalanced adverse moment transmitted to columns. The technique means that the projected extra rise in shear stress due to the time transferred from slab to column is 15%, 30%, 50% respectively for the column inside, outside and corner. The shear stress is caused by

$$q_{up} = \frac{\beta . V_u}{b_o . d} \leq q_{cup}$$

The Egyptian code states that the lowest of the following three values was the concrete punching shear force q_{cup}

$$q_{cup} = 0.316(0.5 + \frac{a}{b})\sqrt{\frac{f_{cu}}{\gamma_c}}$$

$$q_{cup} = 0.8(\frac{\alpha d}{b_o} + 0.2)\sqrt{\frac{f_{cu}}{\gamma_c}}$$

$$q_{cup} = 0.316\sqrt{\frac{f_{cu}}{\gamma_c}} \leq 1.6\ N/mm^2$$

Where:
V_u Ultimate design shear force acting at the critical section.
q_{up} Maximum vertical shear stress generated by an unbalanced moment and vertical force.
β Ratio of complete shear stress to shear stress due only to vertical load depending on column place.
Bo Critical shear perimeter **Fig.5** *d* Effective slab depth.
q_{cup} Concrete ultimate punching shear strength.
a, b Short and long side of the column respectively.
α 2,3, and 4 for corner, exterior and interior column respectively.
f_{cu} Characteristic strength of concrete.
γ_c Strength reduction factor of concrete.

4.1.4.2 Punching shear in ACI 318-08 [39]

The slab fracturing along planes, which extends from the patch-loaded region through the slab depth in an inclined direction away from that region, is anticipated to cause punching shear failure. The shear stress due to factored loads q_u is calculated for concentrated loading as:

$$v_u = \frac{V_u}{b_o . d} \leq V_c$$

For ACI 318-08 *Vc* shall be the smallest of the following three values.

$$V_c = 0.083(2 + \frac{4}{\beta})\lambda\sqrt{f'c}$$

$$V_c = 0.083(\frac{\alpha_{s\ d}}{b_o} + 2)\lambda\sqrt{f'c}$$

$$V_c = 0.083x4\lambda\sqrt{f'c}$$

Where:
Vu Ultimate design shear force due to factored loads
Vu Maximum vertical strain caused by vertical force and unbalanced moment
B Ratio of long side to short side of the column
bo Shear critical section perimeter at d/2 from the bottom of the column, **Fig.8**
d Effective slab thickness for shear
Vc Nominal punching shear strength provided by concrete
αs 40 for interior columns, 30 for edge columns, 20 for corner columns respectively
fc Compressive strength
λ Modification factor reflecting the reduced mechanical properties of light weight concrete , λ =1 for OPC concrete

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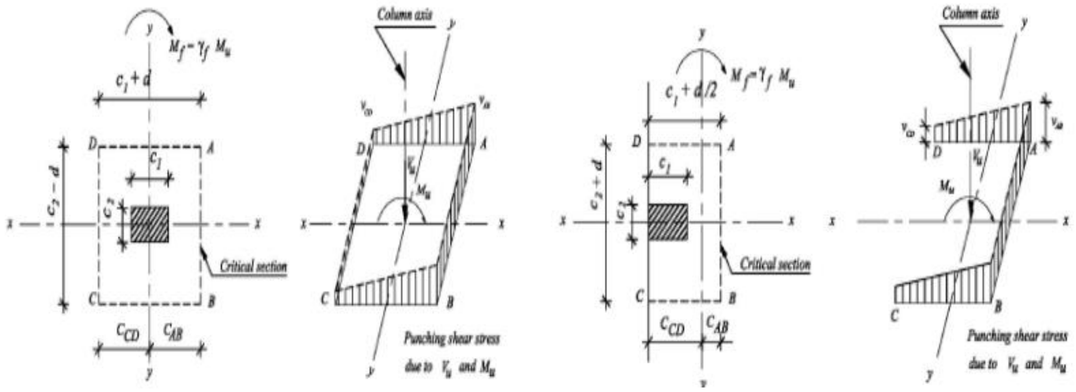

a- Shear stress distribution in case of interior column   b- Shear stress distribution in case of edge column

Fig.5: Punching stress distribution due to an unbalanced moment

4.1.5 Punching Shear Capacity with Addition of Steel Fibres

In order to calculate the total punching shear capacity V_{Rd}, c_f in a reinforced concrete slab of steel fibre, it is suggested that the punching shear capacity of the ordinary reinforced concrete slab V_{Rd}, c be combined with the shear capacity V_{Rd}, f achieved from steel fibre:

$$V_{Rd,cf} = V_{Rd,c} + V_{Rd,f}$$

Two distinct calculation options were evaluated in the following to explore how adaptable they are to assess the ability of reinforced concrete made from steel fibre.

4.2 Slabs with Opening

British standards BS8110 [40] and **Egyptian code [41]** limits the opening sizes in flat plates as follows:

A)-Opening in field striped regions may take place provided that: -

- Their largest dimension does not exceed 0.4 L, **Fig.6 and Fig.7** in a direction parallel to a middle row of the panel.
- In order to meet the changed condition, total positive and negative design moments are redistributed among the remaining structures.

B) It may be possible to open two column strips in prevalent fields provided that:-

- Their width or length of the column strip does not exceed one-tenth of the width.
- Reduced segments can withstand suitable moments.
- The calculation perimeter of the shear stress model is decreased.

C) Column strip and center strip regions may be opened provided that:-

- Their width or length of the column strip does not exceed one-quarter of the width.
- Reduced segments can withstand the right design time.

The **American code ACI-318 [42]**, the **Canadian code CAN3- A23.3-M84 [43]** and the **Australian code AS3600- 88 [44]**do not require unique assessment to open in flat slab with the following:-

1. Opening of any size may be located in the common area of intersecting middle strips, provided in **Fig.8** the total amount of reinforcement required for the panel without opening.
2. No more than one-eighth of the width of the column strips in each span shall be interrupted by opening in the common area of intersecting column strips. The sides of the opening are to be added an amount of reinforcement equivalent to that interrupted by an opening.
3. Not more than one-quarter of the reinforcement in either strip shall be interrupted by opening in the common area of one column strip and one middle strip. The sides of the opening are to be added an amount of reinforcement equivalent to that interrupted by opening.

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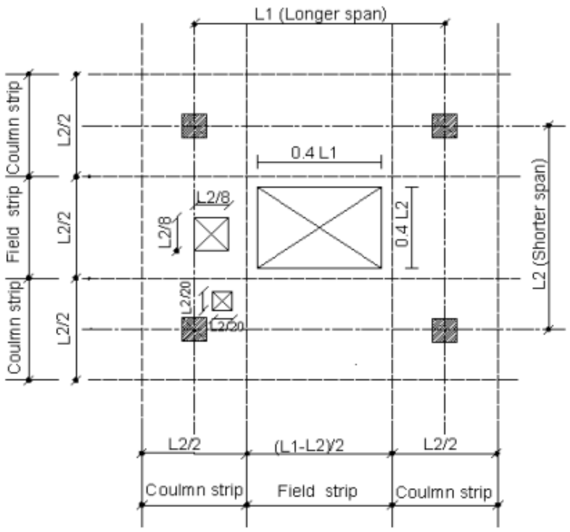

Fig.6: Opening in flat slabs According to BS8110 [40]

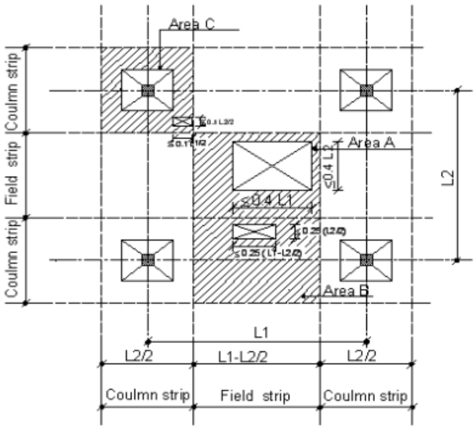

Fig.7: Opening in flat slabs According to Egyptian code [41]

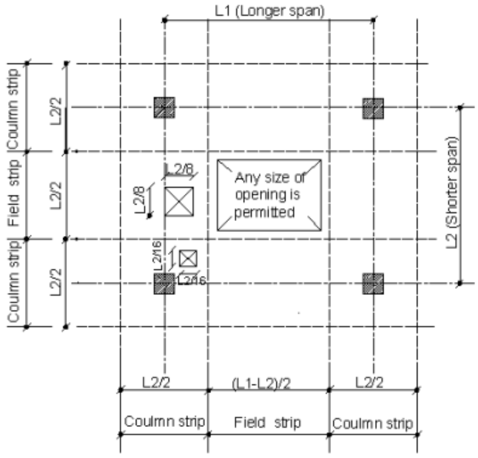

Fig.8: Opening in flat slabs According to ACI -318, CAN3-A23.3-M84, AS3600-88 [42],[43]& [44]

5. PREVIOUS WORK OF PUNCHING SHEAR ON CONCRETE SLABS

The aim of this part reviews the state-of - the-art study job carried out with and without opening on the punching shear failure analysis of reinforced concrete slabs.

5.1 Experimental Studies

Harajli et al. [45], experimental fibre reinforced concrete (FRC) slab-column connections were tested, the impact of parameters was examined: fibre content and aspect ratio and slab span-depth ratio. The findings showed that; steel fibres improved the ultimate resistance of slabs to punching shear. The rise in punching shear load owing to the presence of steel fibres is mainly regulated by the volume fraction of steel fibres used and is independent of the size or aspect ratio of fibres, steel fibres reduced the shear failure plane angle of the plates and thus pushed the fault surface away from the column face.

H. Masuya et al. [46], researched impact-reinforced concrete slab perforation of steel fibre. Three types of steel fibre volume ratio in concrete, i.e. Vf= 0%, 0.5%, 1.0% were used. For each volume ratio, specified tests were performed three times. The size of test specimen of SFRC is 75 x 75 x 5 cm. The steel fibre was 3.0 cm long, 0.05 cm in diameter and 60 cm in aspect ratio. Before blending with water-soluble adhesive material, the fibres have hooks on both ends that are bundles. The findings showed that reinforced concrete slab steel fibre has elevated efficiency for impact perforation due to improved concrete toughness. The mode of failure and the energy up to full perforation of the reinforced concrete slab of steel fibre has become clear.

Schreiber and Alexander [47], experimentally explored the impact of reinforcing steel fibre from an internal slab-column attachment. Under cyclic lateral loading, two full-scale isolated slab-column connections were screened to determine the impact of adding corrugated steel fibres to the concrete on the connection's shear ability. Results showed that adding steel fibres improved shear and flexural capacity, enhanced tensional rigidity, and considerably enhanced connection ductility.

Mohamed et la [48], the feasibility of using distinct reinforcement methods was investigated ; twenty 165x165x8 cm strengthened concrete slabs with a typical 40x40 cm square reinforcement opening were evaluated for failure. Test parameters included the sort of reinforcement material (carbon fibre sheets, steel sheets and carbon fibre strips), opening place (core, edge, corner) and charging pattern (standardized distributed load over the opening sides of the slab or row load). Experimental findings showed that in either distributed load or line load cases, steel plates are more effective than both CFRP sheets and CFRP strips. Slabs reinforced with steel plates showed greater strength, lower deflection, and greater ductility than slabs reinforced with CFRP sheets.

Essa, A. [49], carried out an experimental investigation of seventeen slab-column connection specimens, parametric studies are regarded on the impact of several parameters including: concrete strength, opening size, opening distance to column edge, slab reinforcement ratio, different types of enhancing the punching strength around the opening as adding steel fibres, provide stirrups around the opening. The findings stated that the current opening close to a column not only decreases the punching ability but also improves the worst post-punching conduct and none of the shear improvement methods studied around opening change the failure mode, but both improve the punching ability, ductility and post-punching behaviour.

Yousef, Y.A. [50], experimentally explored the efficiency of reinforced concrete slabs with core opening reinforced externally with CFRP laminates (Carbon Fibre Reinforced Polymers). Seven slabs with dimensions 1650x1650x60 mm were included in the test program. The experimental findings showed a viable technique of enhancing RC slabs using externally bonded CFRP strips. Strengthening RC slabs with externally bonded CFRP considerably raises the ultimate slab load, while slab ductility considerably declines.

Zainab Abdul Rasoul [51], researched the impact of punching shear strength on the behavior of two-way slab samples of self-compacting reinforced concrete with distinct kinds of opening. An experimental test was performed in these studies. For this matter, seven plates were prepared divided into two groups. The various parameters included in this research are: opening forms (square opening, circular opening) and opening position (punching failure). The steady parameters considered are the relationship between concrete type (self-compact) and steel reinforcement. Some of the findings in this research are; the slab's ultimate punching shear strength with the bigger opening is less than that with the narrower one and at the border for square opening, and the slab specimen's ultimate load capability was considerably reduced when opening occurred.

BANU et al [52], presented the results obtained from the testing of eight two-way reinforced concrete (RC) slabs with or without opening reinforced with composite strips bonded to the elements ' tensioned face. A 29% increase in load carrying capacity and a decrease in deflection of up to 57% compared to the unstregthened slab are accomplished for the reinforced slabs without opening. The reinforced opening plates had an increase of 115 % in load carrying capacity and a decrease of up to 74 % in deflection compared to the control specimen. The reinforced slabs showed a gradual failure regulated by the flexural failure.

Borges et.la [53], studied the punching shear behavior on 13 flat concrete reinforced plates with and without opening or shear reinforcement. The opening (one or two) were adjacent to the rectangular supports ' shorter sides and had widths equal to the supports. The findings show that the provision of ongoing bars adjacent to opening to replace the reinforcement regions appears to be an appropriate approach to flexural design for the comparatively tiny opening considered. It is suggested that the shear stress used for concrete in ACI 318-11 could be enhanced for strength evaluation at the corners of shear-reinforced areas (exterior control perimeter).

Sunil kumar M S et.la [54], experimented with and without opening the behavior of self-compacting RC slab.14 slabs of size 600X600X60 mm are cast, out of these 14 slabs 2 slabs are cast without opening and the remaining slabs are cast with different opening sizes and shapes such as 50 mm square opening and 150 mm square opening (with and without diagonal reinforcement) and 50 mm circular opening and 150 mm circular opening (with and without diagonal reinforcement).The plates are loaded at 4 points. Compared to slab without opening, the proportion reductions in strength of slabs with opening are as shown below. **1)** Reduce the strength of the 50 mm square opening slab by 6%. **2)** The slab strength decrease with a circular opening of 50 mm is 4.10%.

Chkheiwer et.La [55], submitted an experimental study on the capacity to use wire mish reinforcement and steel fibre to restore the slab's flexural strength after configuring opening cut with various forms. Fifteen plates (800 * 800 * 95 mm) made of high-strength concrete were prepared and tested,

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split into groups, the first group consisted of square opening, and the second group consisted of rectangular opening. Wire mish (with distinct layers and widths) strips around opening and steel fibres were used for each group of two distinct reinforcement methods (with four contents of 0, 0.5, 1.0 and 1.5 percent by volume fraction).The results showed that wire mish and steel fibre reduced the cracks on the opening inside faces and also increased the load-bearing capacity of the opening slabs compared to the slabs without reinforcement.

Karunanithi et al [56], presented experimental studies on shear punching and reinforced slag-based geopolymer concrete impact resistance of steel fibre. The different proportion of steel fibre in slag-based geopolymer concrete was 0.5%, 1.0%, and 1.5%.Overall, the 0.5% dosage of steel fibre reinforced slag based geopolymer showed better results with a punching shear of 224 kN and 1.0% of steel fibre integrated geopolymer concrete had better power absorption ability with 3774.40 N for first crack toughness and 4123.88 N for ultimate failure toughness.

The prospective impact of steel fibre added to reinforced concrete slabs was investigated experimentally by **Baarimah et al [57]**. The experimental work comprises of six plates in which three plates are designed to fulfill the criterion of shear capability in accordance with Eurocode 2. In order to study the effect and potential of fibre to compensate for the loss in shear capacity, both series of slabs are added with steel fibre with a volume fraction of V_f= 0%, 1 % and V_f= 2 %. The experimental tests indicated promising improvements in load carrying ability (up to 32%) and ductility (up to 87%) as well as delays in crack propagation for the V_f= 2% plates.

Landler et al [58], investigated the load capacity behaviour of the slab-column connection using double-hooked-ends fibre reinforced concrete. The parameters were the slab thickness with 250 mm and 300 mm and the fibre content V_f with 0.5% and 1.0%. From the experiments, it was depicted that the load bearing using fibre reinforced concrete increased by 20 % to 50 % compared to the reference tests without steel fibres, depending on the fibre type and the fibre content V_f. An effect of the slab thickness or steel fibre type on the shear strength contributed by the fibre reinforced concrete could not be determined.

The behaviour of reinforced and fibre reinforced geopolymer concrete slabs with openings under punching shear was examined experimentally and analytically by **Marwa A. Sadawy et al. [59]**. 24 square reinforced concrete slabs with a square column of 100x100x300mm and having a constant dimension of 1000x1000x100mm were tested. The type of concrete, the opening's location in relation to the column, and the volume ratio of concrete steel fibre were the variables examined. The reinforced slab-column connections were modelled using the finite element programme (ANSYS V14.5). It has been shown that utilising steel fibre and geopolymer concrete improves the ultimate load capacity of slabs. Geopolymer concrete slabs with fibre reinforcement (FRGPC) had a higher maximum load capacity than conventional Portland cement (OPCC) reinforced concrete.

In order to assess the punching shear strength of concrete slabs including a combination of recycled coarse aggregate (RCA) and crumb rubber, **Mahmoud Elsayed et al. [60]** conducted experimental, analytical, and computational experiments. Twelve 1000 x 1000 x 100 mm, two-way, simply supported RC slabs were cast and put to the test. According to experimental findings, concrete's mechanical characteristics are adversely impacted by the combination of coarse aggregate (RCA) and crumb rubber (CR). The loss of the concrete strengths was significantly impacted more by the rubber content substitution ratios than by the RCA content. The experimental findings were compared to the predictions of five different methodologies, including ACI 318-2014, ECP 203, Euro 2, BS8110, and CSA A23.3. Lastly, nonlinear element analysis (ANSYS) was carried out to use numerical methods to confirm the experimental data.

Sarwar Hasan Mohmmad et al [61], studied experimentally the punching shear and deflection performance of 16 Geopolymer concrete (GC) two-way slabs subjected to monotonic and cyclic loading by considering the reinforcement material, percentage of reinforcement, type of concrete and the concrete grade. The tested slabs indicated that the crack patterns at the failure and failure modes were almost similar regardless of the type of reinforcement or their ratio. The results showed that the punching shear performance of GC slabs was found to be better than that of ordinary concrete (OC). Further, the slabs reinforced by FRP had a better fatigue performance compared with slabs reinforced by steel bars with respect to cyclic loading.

5.2 Analytical Studies

Guan, H., [62], using the non-linear Layered Finite Element Method (LFEM) numerical assessment to estimate the impact of opening on shear punching failure conduct of slab column links with shear stud strengthening (SSR). All twenty-one (21) models were examined in six parametric researches, including varying the size and place of the opening and varying the aspect of the column. This inquiry was a significant step towards determining the opening size and place and column size for optimum flat plate system structural performance.

Park et al. [63], created a model of strength to predict the direct punching shear strength of inside slab-column links without shear reinforcement. The suggested model's punching shear mechanism can be summarized as follows; Due to either compression distortion or tensile cracking, the compression area of the critical section under mixed compressive stress and shear stress fails. A slab-column connection's punching shear resistance is primarily influenced by the concrete's tensile strength and compression area depth. As the flexural reinforcement ratio rises, the compression area depth rises, thereby increasing the power of the punching shear.

Gawaset La [64], provided finite element analysis of RCC slab models to study displacement variation and stress variation in slabs with distinct boundary conditions. Using ANSYS 10 Software, non-linear static analysis was performed and a rectangular RC slabs with tensile reinforcement were analyzed. Comparing the slabs with different boundary conditions with and without opening, the slab that is simply supported on all edges shows the highest displacement and the slab that is fixed on all edges shows the least displacement. The slab that has fixed support with and without opening on all corners indicates the greatest stress, whereas the slab that is simply supported on all corners indicates the least stress among all other slabs.

M. Elsayed [65], investigated the structural conduct of the reinforced concrete slab with a centered square opening reinforced by the nonlinear finite element analysis of ferrocement laminates. The parameters investigated were: ferrocement layer thickness, proportion of extended wire mesh enhancement in the ferrocement cover layer, mortar compressive strength. The findings showed that the use of ferrocement allows the plates to restore their complete load ability and to increase their ultimate load ability by up to 2 times.

V. Kavinkumar.et la [66], researched Self Compacting Concrete (SCC) mechanical characteristics as well as punching shear failure of SCC plates. This program involves researching the impact of SCC, slab thickness in terms of load deflection reaction and ultimate failure load on the punching shear behaviour, Simply supported slabs of 1000 x 1000 x 50 and 75 mm under focused load in the center of the slab failure trait of punching shear failure (shape of failure area and size of failure area). Both SCC and conventional concrete (CC) make the slabs. Research included two-way samples with distinct thicknesses to assess sample quality with distinct thicknesses and the impact of density on shear performance and punching ability.

6. SUMMARY AND CONCLUSION

This paper provided a review summery on the behaviour of reinforced concrete slabs under punching shear. Literature review is split into two parts. Based on this prior research, an experimental and theoretical research should be carried out to explore the conduct of reinforced and fibre-reinforced geopolymer concrete slabs with opening under punching shear, taking into account various parameters such as different concrete types, location of opening w.r.t the column and volume ratio effect of steel fibre in concrete. Experimental findings are suggested to derive a numerical model to assess the punching shear behaviour of reinforced and strengthened concrete slabs with opening using geopolymer concrete. Using geopolymer concrete improved the mechanical properties such as compressive strength. The presence of opening in slab decreased the ultimate load capacity. Punching failure strength of geopolymer reinforced concrete slabs with and without opening was better than of OPCC slabs with and without opening. Therefore, geopolymer concrete resisted punching better than OPC concrete.

REFERENCES

[1] Mccaffrey, R., "Climate change and the cement industry", *Global cement and lime magazine (environmental special issue)*, *15*, p.19, 2002.

[2] Gartner, E., "Industrially interesting approaches to "low-CO2" cements". *Cement and Concrete research*, *34*(9), pp.1489-1498, 2004

[3] Josa, A., Aguado, A., Heino, A., Byars, E. and Cardim, A., "Comparative analysis of available life cycle inventories of cement in the EU", *Cement and Concrete Research*, *34*(8), pp.1313-1320, 2004.

[4] Duxson, P., Fernández-Jiménez, A., Provis, J.L., Lukey, G.C., Palomo, A. and van Deventer, J.S., Geopolymer technology: the current state of the art. *Journal of materials science*, *42*(9), pp.2917-2933, 2007.

[5] Salwa, M.S., Al Bakri, A.M., Kamarudin, H., Ruzaidi, C.M., Binhussain, M. and Zaliha, S.S., "Review on current geopolymer as a coating material". *Australian Journal of Basic and Applied Sciences*, *7*(5), pp.246-257, 2013.

[6] Rowles, M. and O'connor, B., "Chemical optimisation of the compressive strength of aluminosilicate geopolymers synthesised by sodium silicate activation of metakaolinite", *Journal of materials chemistry*, *13*(5), pp.1161-1165, 2003.

[7] Provis, J.L. and Van Deventer, J.S.J. eds., " *Geopolymers: structures, processing, properties and industrial applications"*, Elsevier, 2009

[8] Davidovits, J., " Geopolymers: man-made rock geosynthesis and the resulting development of very early high strength cement", *Journal of Materials education*, *16*, pp.91-91, 1994.

[9] Plus, M.T., "Environmental implications of Geopolymers", 2013.

[10] Hanjitsuwan, S., Hunpratub, S., Thongbai, P., Maensiri, S., Sata, V. and Chindaprasirt, P., "Effects of NaOH concentrations on physical and electrical properties of high calcium fly ash geopolymer paste" *Cement and Concrete Composites*, *45*, pp.9-14, 2014.

[11] Pacheco-Torgal, F., Castro-Gomes, J. and Jalali, S., "Alkali-activated binders: A review: Part 1. Historical background, terminology, reaction mechanisms and hydration products", *Construction and Building Materials*, *22*(7), pp.1305-1314, 2008.

[12] Ye, N., Yang, J., Liang, S., Hu, Y., Hu, J., Xiao, B. and Huang, Q., "Synthesis and strength optimization of one-part geopolymer based on red mud", *Construction and Building Materials*, *111*, pp.317-325, 2016.

[13] Davidovits, J., "Geopolymers and geopolymeric materials", *Journal of thermal analysis*, *35*(2), pp.429-441, 1989.

[14] Davidovits, J., "Properties of geopolymer cements" In *First international conference on alkaline cements and concretes* (Vol. 1, pp. 131-149). Kiev State Technical University, Ukraine: Scientific Research Institute on Binders and Materials, 1994.

[15] Sakulich, A.R., "Reinforced geopolymer composites for enhanced material greenness and durability", *Sustainable Cities and Society*, *1*(4), pp.195-210, 2011.

[16] Motorwala, A., Shah, V., Kammula, R., Nannapaneni, P. and Raijiwala, D.B., "Alkali activated fly-ash based geopolymer concrete", *International journal of emerging technology and advanced engineering*, *3*(1), pp.159-166, 2013.

[17] Swanepoel, J.C. and Strydom, C.A., "Utilisation of fly ash in a geopolymeric material", *Applied geochemistry*, *17*(8), pp.1143-1148, 2002.

[18] Davidovits, J., "Chemistry of geopolymeric systems, terminology", In *Geopolymer* (Vol. 99, No. 292, pp. 9-39), 1999.

[19] Palomo, A., Grutzeck, M.W. and Blanco, M.T., "Alkali-activated fly ashes: A cement for the future", *Cement and concrete research*, *29*(8), pp.1323-1329, 1999.

[20] Kostuch, J.A., Walters, G.V. and Jones, T.R., "High performance concretes incorporating metakaolin: a review", *Concrete*, *2*(1993), pp.1799-811, 2000.

[21] Fan, F., "Mechanical and thermal properties of fly ash-based geopolymer cement, 2014.

[22] Van Jaarsveld, J., and Van Deventer, J. S. J., "Effect of the alkali metal activator on the properties of fly ash-based geopolymers", *Industrial & engineering chemistry research*, *38*(10), pp.3932-3941, 1999.

[23] Škvára, F., "Alkali activated material–geopolymer", In *International Conference Alkali Activated Materials–Research, Production and Utilization, Českározvojováagentura, Praha*, pp. 21-22, 2007.

[24] Hardjito, D., "Studies of fly ash-based geopolymer concrete", (Doctoral dissertation, Curtin University), 2005.

[25] Ramujee, K., "Development of low calcium flyash based geopolymer concrete", *International Journal of Engineering and Technology*, *6*(1), 1, 2014.

[26] Xu, H., and Van Deventer, J. S., "Ab initio calculations on the five-membered alumino-silicate framework rings model: implications for dissolution in alkaline solutions". *Computers & chemistry*, *24*(3-4), pp.391-404, 2000.

[27] Tempest, B., Sanusi, O., Gergely, J., Ogunro, V., and Weggel, D., "Compressive strength and embodied energy optimization of fly ash based geopolymer concrete", In *world of coal ash (WOCA) conference*, pp. 1-17, 2009.

[28] Davidovits, J., "Application of Ca-based geopolymer with blast furnace slag", a review. In *2nd International Slag Valorisation Symposium*, pp. 33-49, 2011.
[29] Shah, S. P., '1981, March. Fibre Reinforced Concrete', *Concrete Construction*, 26(3), pp. 261-266.1981.
[30] Thompson, J.R. and Tepfer, M., "Assessment of the benefits and risks for engineered virus resistance", In *Advances in virus research* (Vol. 76, pp. 33-56), 2010.
[31] Gardner, N.J., Huh, J. and Chung, L., Lessons from the Sampoong department store collapse. *Cement and Concrete Composites*, *24*(6), pp.523-529, 2002.
[32] Muttoni, A., "Punching shear strength of reinforced concrete slabs without transverse reinforcement", *ACI structural Journal*, *4*(ARTICLE), pp.440-450, 2008.
[33] Loo, Y.C. and Guan, H., "Cracking and punching shear failure analysis of RC flat plates", *Journal of structural engineering*, *123*(10), pp.1321-1330, 1997.
[34] Eder, M.A., Vollum, R.L., Elghazouli, A.Y. and Abdel-Fattah, T., "Modelling and experimental assessment of punching shear in flat slabs with shearheads", *Engineering Structures*, *32*(12), pp.3911-3924, 2010.
[35] Mamede, N.F.S., Ramos, A.P. and Faria, D.M., " Experimental and parametric 3D nonlinear finite element analysis on punching of flat slabs with orthogonal reinforcement", *Engineering structures*, *48*, pp.442-457, 2013.
[36] Broms, C.E., " Ductility of flat plates: Comparison of shear reinforcement systems", *ACI Structural Journal*, *104*(6), p.703, 2007.
[37] Koppitz, R., Kenel, A. and Keller, T., "Punching shear of RC flat slabs–Review of analytical models for new and strengthening of existing slabs", *Engineering Structures*, *52*, pp.123-130, 2013.
[38] Fernández Ruiz, M., Mirzaei, Y. and Muttoni, A., "Post-punching behavior of flat slabs", *ACI Structural Journal*, *110*(ARTICLE), pp.801-812, 2013.
[39] Sagaseta, J., Muttoni, A., Ruiz, M.F. and Tassinari, L., "Non-axis-symmetrical punching shear around internal columns of RC slabs without transverse reinforcement". *Magazine of Concrete Research*, *63*(6), pp.441-457, 2011.
[40] BS8110, P., 1: British Standard: structural use of concrete: code of practice for design and construction. *British Standards Institution, UK*, 1985.
[41] Code, E., "Egyptian Code of Practice for Concrete Structures", HBRC. *Arabic, Cairo, Egypt*, 2007.
[42] Committe, A.C.I., " Building Code Requirements for Structural Concrete (ACI 318-95) and Commentary (ACI 318R-95)". American Concrete Institute, 1995.
[43] Ghali, A. and Megally, S., "Design for punching shear in concrete: critical review of Canadian Standard CSA-A23. 3-94". *Canadian journal of civil engineering*, *23*(2), pp.444-456, 1996.
[44] Mohamed, E.M.A.A.A., "BEHAVIOR OF FLAT SLABS WITH OPENINGS ADJACENT TO COLUMN" (Doctoral dissertation, Faculty of Engineering, Tanta University, Egypt 2011), 2004.
[45] Harajli, M.H., Maalouf, D. and Khatib, H., "Effect of fibres on the punching shear strength of slab-column connections". *Cement and Concrete Composites*, *17*(2), pp.161-170, 1995.
[46] Masuya, H., Yamamoto, M., Toyama, M. and Kajikawa, Y., "Experimental study on the perforation of steel fibre reinforced concrete slab by impact". *WIT Transactions on the Built Environment*, *48*, 2000.
[47] Schreiber, S.K. and Alexander, S.D., "Punching shear capacity of slab-column connections with steel-fibre reinforcement under lateral cyclic loading", 2001.
[48] Mohamed, T., El-Attar, A. and El-Ibiari, S., " Strengthening of Two-Way Reinforced Concrete Slabs with Created Central Openings", In *Regional Conference on Civil Engineering Technology and III International Symposium on Environmental Hydrology, Egypt*, 2002.
[49] Essa, A., *"Punching of high strength concrete flat plates with openings*", (Doctoral dissertation, Ph-D. Thesis, Cairo University, 2003.
[50] Yousef, Y.A., '2007. Strengthening of Two Way R.C Slabs with Openings Using CFRP Laminates', *(Doctoral dissertration, Ph-D. Thesis, Cairo University)*.2007.
[51] Zainab Mohammed Abdul Rasoul, '2011. Experimental Study of Punching Shear Strength of Self Compacting Concrete Slabs with Openings', *Journal of Kerbala University*, 9(2), pp. 88-100.2011.
[52] BANU, D., ŢĂRANU, N., DE BARROS, R.C., CIOBANU, P. and POPOAEI, S., " Experimental Study of Two Way RC Slabs with or without Openings Strengthened with Composite Strips", *Bulletin of the Polytechnic Institute of Iasi-Construction & Architecture Section*, *62*(3), 2012.
[53] Borges, L.L., Melo, G.S. and Gomes, R.B., "Punching shear of reinforced concrete flat plates with openings", *ACI Structural Journal*, *110*(4), pp.547-556, 2013.
[54] Sunil kumar M S, B. S. Suresh Chandra, '2014. Experimental Study on Self Compacting RC Slab With and With Out Opening', *International Journal of Engineering Research & Technology (IJERT)*, 3(8), pp. 202-206.2014.
[55] Chkheiwer, A.H. and Abdullah, M.D., "Flexural Behavior of High Strength RC Slabs with Opening Strengthening with Wire Mish and Steel Fibres", *Kufa Journal Of Engineering*, *8*(3), pp.103-118, 2017.
[56] Karunanithi, S., "Experimental Studies on Punching Shear and Impact Resistance of Steel Fibre Reinforced Slag Based Geopolymer Concrete", *Advances in Civil Engineering*, *2017*.
[57] Baarimah, A.O. and Mohsin, S.S., "Behaviour of reinforced concrete slabs with steel fibres", In *IOP Conference Series: Materials Science and Engineering* (Vol. 271, No. 1, p. 012099). IOP Publishing, 2017.
[58] Landler, J. and Fischer, O., "Punching Shear Capacity of Steel Fibre Reinforced Concrete Slab-Column Connections", 2019.
[59] Marwa.A.Sadawy, A.Serag Faried, and H.A. El-Ghazaly, "Investigating the Impact of Punching Shear Strength on Geo-Polymer Concrete Slabs with Openings", Design Engineering, Issue: 8, pp.9148-9161, 2021.
[60] Mahmoud Elsayed, Bassam A. Tayeh, Mai Mohamed, Magdy Elymany, and Ahmed Hamdi Mansi, "Punching shear behaviour of RC flat slabs incorporating recycled coarse aggregates and crumb rubber", Journal of Building Engineering, vol.44, 103363, 2021.
[61] Sarwar Hasan Mohmmad, Mehmet Eren Güls, and Abdulkadir Çevik, "Punching shear behaviour of geopolymer concrete two-way slabs reinforced by FRP bars under monotonic and cyclic loadings", Advances in Structural Engineering, Vol. 25(3), pp. 453–472, 2022.
[62] Guan, H., "Prediction of punching shear failure behaviour of slab-edge column connections with varying opening and column parameters", *Advances in structural engineering*, *12*(1), pp.19-36, 2009.
[63] Park, H.G., Choi, K.K. and Chung, L., "Strain-based strength model for direct punching shear of interior slab–column connections", *Engineering structures*, *33*(3), pp.1062-1073, 2011.
[64] Gawas, S. and Itti, S.V., "Study on Two way RC Slab using ANSYS with and without central opening" *International Journal of Scientific Engineering and Technology*, *3*(8), pp.1108-1110, 2014.
[65] M.El sayed "Numerical Analysis of Strengthening R.C Slabs with Opening using Ferrocement Laminates", International Journal of Engineering Research &Technology, 4(6), pp.412-416, 2015.
[66] V. Kavinkumar, and R. Elangovan, '2016. An Analytical and Numerical Investigation on Punching Shear Behaviour of SCC Slab', *IRA-International Journal of Technology & Engineering*, 3(3), pp. 217-228. results.