

BRACKETED FLAT PLATE

FILED OF THE INVENTION

- 5 This invention relates to a structural flat plate/slab system for large office and commercial buildings, wherein brackets are introduced at column slab junctions on its diagonals. This new system will be referred to and known as "Bracketed Flat Plate" hereinafter.

10 BACKGROUND OF THE INVENTION

- The most common structural element in modern buildings is Concrete Slab, which may be either cast in-situ or post tensioned slab. In situ concrete slabs are built on the building site using form-work a type of boxing into which the wet concrete is poured. If the slab is
- 15 to be reinforced, the rebars are positioned within the formwork before the concrete is poured in. Plastic tipped metal, or plastic bar chairs are used to hold the rebar away from the bottom and sides of the form-work; so that when the concrete sets it completely envelops the reinforcement. Structural slab system for large span office and commercial buildings are generally provided as an insitu slab reinforced concrete (RC) construction.
- 20 The following are the different types of structural system.

01. Beam and slab system.
02. Ribbed slab system.
03. Flat slab with drop head system
- 25 04. Flat slab with Post tension system.
05. Waffle slab system
06. Flat plate system (limited to 6m spans)
07. Paneled slab system.

The other type of systems such as precast pre-tensioned system, structural steel metal deck slab system, hollow core slab system are not considered in this context as they are totally of different type of design and construction.

- 5 The column spacing that is generally adopted for commercial buildings varies from 6m to 12m. The above structural systems are generally adopted taking into account the safety, economy and constructability. The most commonly adopted system is FLAT SLAB due to its ease of construction and for getting an unhindered space between the soffit of slab and false ceiling for all services. As the volume of office / Information technology
- 10 projects constructed is increasing in millions of square feet of built up area and the construction industry is looking for more and more cost effective designs thus this innovation.

- Flat plates are elegant, simple, easy and faster to construct and provides uninterrupted
- 15 space for services allowing lesser floor to floor height of the structure. Flat plates/slabs are extensively used for offices, schools, warehouses, hospitals, hotels, car parking structures and commercial buildings. Flat plates are provided for smaller spans and flat slabs for larger spans. Two-way shear or punching shear as described is very brittle and is instantaneous giving no time for escape. There may not be any indications of cracks and
- 20 deflections in this type of failure, i.e., the failures are sudden and also may lead to progressive failures. A failure at one column location may lead to large rotations of slabs and this flexural curvature may reduce the capacity of slabs to resist punching shear at the affected columns leading to progressive collapse. Providing shear reinforcement / shear stirrup cages are expensive and the shear capacity is limited to the overall capacity of
- 25 concrete in taking up the shear with reinforcement.

- In flat plates the load path from the slab to the column is through two-way shear or punching shear. The failure mode in punching shear is a truncated cone surface of concrete and the failure is very sudden and brittle, due to the very highly concentrated
- 30 shear forces around columns. As the demand for large span and economical structures are increasing and secondary problems arising out of gas explosion, impact construction

errors, vibrations are also to be given due consideration, providing column drop heads, capitals have become more acceptable.

A number of design options there are considered in accounting for these highly concentrated shear forces are as given below:

01. Providing drop heads.
02. Usage of column capital.
03. Column capital and drop heads.
- 10 04. Shear reinforcement in slabs including bent rebars, stirrup cages.
05. Structural steel – Shear connectors.

Out of the above design options most commonly used is a flat slab with column heads which to a certain extent reduces the concentration of shear forces around column.

15 Column capital with drop heads improves the system to carry shear forces over an extended area. Shear reinforcement /shear connectors are some of the options to take advantage of the full capacity of the concrete sections adopted for the design. However in all the above systems the mode of transfer of loads is through two-way punching shear. Hence the need for an improved, safe and economical approach to the design of flat slabs,

20 necessitating a re-look at the load path at the column-slab junction.

SUMMARY OF THE PRESENT INVENTION

The object of the present invention is to provide a bracketed flat plate system, which is safer, economical and construction friendly.

In the present invention load is dissipated from flat slabs to columns through one-way shear and bending, rather than through punching shear as in the case of normal flat slab construction.

Structures constructed in recent times require that it shall be designed so that it will not be damaged by explosions, impact, consequences of construction errors and vibrations apart from primary requirements of strength, stability and serviceability as per the IS codes. This implies that local failures must not lead to progressive collapse of the entire structure either due to construction errors or due to gas explosions and hence the need for solutions that could prevent such failures, which is a very significant one. The punching shear failure mode of the failure surface is in the form of a truncated pyramid cone around the column and is at a distance of $D/2$ where "D" is the thickness of the slab/drop head. The punching shear capacity is thus governed by diagonal tensile strength of the concrete which occurs in the normal cases of loading; at 2/3rds of ultimate loads and the cracks around the column appear at this stage although it may not decrease the ultimate capacity of slab in punching shear. The mode of failure is attributed to the flexural curvature of the slab of compression zone at column junction.

The above theory thus clarifies that, the shear rebars, shear studs, shear strips does not give the desired results but still persist with the brittle punching shear failure.

The research and requirements of the code to make the column slab junction a ductile one and avoid punching shear failure is made possible by providing brackets on its diagonals. The rebars in the brackets take up bending and tension and the stirrups provided in the brackets take up shear forces.

BRIEF DESCRIPTION OF THE DRAWINGS

- Fig.1 Illustrates the bracketed flat plate of the present invention;
Fig.2A, 2B,2C Illustrate the sectional elevations of the bracketed flat plate of the present invention;
Fig.3 Illustrates the isometric view of the bracketed flat plate showing two floors;
Fig.4 Illustrates the isometric view of the bracketed flat plate showing single floor;
Fig.4a Illustrate the arrangement of bottom rebars in X and Y direction:

Fig.4b Illustrate the arrangement of top rebars in X and Y direction:

Example: Fig. 05 Illustrate the bracketed flat plate of the arrangement of brackets on the column diagonals

Example : Fig. 06 Illustrate the sectional elevations of the bracketed flat plate

5 Example: Fig. 07 Illustrate the computer model of the bracketed flat plate

Example: Fig. 08 Illustrate the moment contour in X direction.

Example: Fig. 09 Illustrate the moment contour in Y direction.

Example: Fig. 10 Illustrate the deflection contour of the bracketed flat plate.

Example: Fig. 11 Illustrate the arrangement of bottom rebars in X direction:

10 Example: Fig. 12 Illustrate the arrangement of bottom rebars in Y direction:

Example: Fig. 13 Illustrate the arrangement of top rebars in X direction:

Example: Fig. 14 Illustrate the arrangement of top rebars in Y direction:

Example: Fig. 15 Illustrate the arrangement of top rebars in the bracket.

15 Example: Fig. 16 Illustrate the arrangement of rebars in the bracket - section at intermediate column location.

Example: Fig. 17 Illustrate the arrangement of rebars in the bracket - section at edge/corner column location.

DETAILED DESCRIPTION OF THE INVENTION

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The present invention has diagonal brackets 1 which is tapered in depth at column-slab junctions and are extending upto length of $L/4$ from the center of the column 2 along X and Y axes and having depths of $L/9$ - $L/10$ at column end 2 and $L/25$ - $L/28$ at free end 3, where "L" is the length spanning between the columns in X and Y directions. Columns 4 oriented diagonally with reference to X and Y directions facilitate the construction and placement of rebars in brackets.

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The brackets 1 which are tapered at the bottom look elegant and have all the advantages of flat slabs in providing the services under the ceiling. Brackets could be varied in depths and widths to accommodate design forces.

Bracketed flat plates reduces the overall thickness of the slab thus saving substantial amount of concrete and rebar quantities when compared to flat slabs of similar span. Rebars used in the bracketed flat plate is placed the same pattern as flat slabs and the rebars in bracket are placed diagonally within the beam and portion of the rebars are extended into the flanges thus avoiding congestion of steel at the column-bracket junction. The pouring of concrete within the bracket is also easier as only a small height of the column has to be poured directly from the top of the slab.

In high rise structure the grades of concrete varies in columns and slabs, higher grade being used in columns and lower grade in slabs. The columns are cast first with the higher grade of concrete followed by slab with concrete of lesser grade in order to reduce the cost of construction. As the dead load of the slabs including the bracket is reduced, there will be intangible benefit in column and foundation designs.

The flat slab construction may be of cast in-situ concrete with rebars or post-tensioned slabs with lesser quantity of rebars. Application of this invention can be in cast in-situ flat slabs, flat plates, post-tensioned slabs, tendons, waffle slabs, ribbed slabs, voided slabs and foundations.

Application of the bracketed flat plate system varies with usage patterns, such as commercial, car parks, hotels, residential, hospitals and office structures and spans varying from 6m to 15m. Larger the spans this invention has advantages of minimizing the materials used and thereby reducing the cost of construction.

The following is the description of above discussion of providing “brackets” for flat slabs and comprises of:

01. Providing diagonal brackets at column slab junctions.
02. Length of brackets on diagonals along X and Y axes is approximately $L/4 - L/5$, “L” being the length between the center to center of columns.
03. Depth of bracket varies from $L/9 - L/10$ at column end to $L/25 - L/28$ at free end.
04. Width of bracket maybe $L/25 - L/28$.

05. The bracketed flat plate is modeled using the geometrical properties of columns, brackets and slab for the floor plate.
06. The bracketed flat plate is subjected to dead load plus live load analysis with lateral loads being resisted by shear/core walls.
- 5 07. Bracketed flat plate shall be provided with a camber at the center of the panel equivalent to immediate dead load deflection.
08. The analysis is carried out using commercial software ETAB-9.7 / STAAD 2007 Pro for dead load plus live load combinations.
09. The output from the analysis is scrutinized and designed for the critical load combinations.
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10. The deflection pattern and the maximum deflection and the secondary conditions defined are checked.
11. The rebars so obtained is provided at the locations as per stress contours.
12. Placement of shuttering may be standardized and repeated for the brackets.
15 Aluminum formwork is preferred for a large number of repetitions.
13. Rebars shall be placed for brackets in-between the column bars, top rebars placed in the beam and a portion extended into the slab.
14. Stirrup shall be provided for brackets as per design.
15. Bottom rebars as required by design are provided in brackets according to the profile of the shuttering.
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16. Top layers of slab rebars are provided on the top of the bracket rebars in orthogonal direction.
17. Slab rebars at bottom surface are provided orthogonally and are extended upto center of column and alternate rebars are curtailed upto $L/4.5$ on either side of the column.
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18. Concrete shall be poured in columns, brackets and slabs as per the grade of the concrete specified in designs.

19. The system transfers the slab loads onto the brackets and thus makes the square/rectangle area around the columns extending till the edge of the bracket into a zone of higher stiffness.
20. The stiffness thus obtained by providing the brackets will prevent the slab having a greater flexural curvature, thereby eliminating the brittle punching shear failure.
21. The bracketed flat plate effectively spans between the edges of the brackets thereby reducing the flexural behavior and thus reducing the thickness of the slabs.
22. The load path of the bracketed flat plate is effectively of one-way shear and bending mode at the column-bracket junction and thus it is a very different mode of transfer of forces than a flat plate/slab.
23. Bracketed flat plate facilitates ductile detailing at the column bracket intersection.

Structural slabs using the "Bracketed flat plate" invention has higher stiffness at column-bracket junctions, a more safer load path, avoids brittle punching shear failure, avoids progressive collapse due to gas explosions and construction errors, accommodates openings around columns without going into detailed design, without affecting the structural behavior and economizes the construction cost.

Example 1:

This Example describes the results of analysis and design of "Bracketed Flat Plate System" for an office floor of Gird 10.8 x 10.8m. The designs are carried out as per the provisions of the Indian codes.

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A 3x3 bay of a normal flat slab spans of 10.8mx10.8m and brackets are shown in Fig. 5. The brackets are tapered varying from 1000mm depth at column to 400mm depth at edges and width of 450mm. The slab thickness provided is 200mm thick throughout, edge beams are 300mm x 900mm. In this example the slab is subjected to an imposed load of 300 kg/sqm, live load of 400kg/sqm apart from the dead load of slab and brackets.

The slab system is analyzed for Dead + Live load only using STAAD Pro / ETAB software. Fig – 05a – Indicates the sectional elevation details of edge beam 300x900mm (A), Brackets depth varying from 1000 to 400mm, width 450mm (B) and (C).

This example subjected to the normal Dead +Live loads for a commercial building demonstrated the load path of the Bracketed Flat Plate system through essentially one way shear and bending. The behavior of the system is within the limits of BIS of India. This example when compared to the normal flat slab system has substantially reduced the consumption of materials which is as follows:

SL. NO	Particulars	Normal Flat Slab	Bracketed Flat Plate	Comparison of Materials
01	Concrete (Cum)	311.60	230.80	(-) 26.0%
02	Rebars (Mt))	25.50	22.50	(-) 12.0 %
03	Shuttering(Sqm)	1083.60	1147.30	(+) 5.6 %

- 10 The bracketed Flat Plate system not only assures a safer load path but also saves enough material.

(-) Indicates Reduction in material.

(+) Indicates Additional in material.

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The advantages of the proposed system can be summarized as follows:

01. Bracketed concrete flat plate structure of the present invention provides all the requisite clearances for services under the ceiling.
- 20 02. Bracketed concrete flat plate of the present invention is safer and avoids brittle punching shear. Bracketed concrete flat plate claims that the secondary requirements of avoiding progressive failure due to gas explosions, human errors in construction.

03. The openings around the columns may be provided and limitations as given for the flat plate/slab structures are not applicable in Bracketed concrete flat plate of the present invention.
- 5 04. Bracketed concrete flat plate of the present invention is more efficient in transfer of forces and uses fewer materials for construction.
- 10 05. A bracketed flat plate system the slab is cast in-situ the rebars or post-tensioned slabs with lesser quantity of rebars.
06. A bracketed flat plate system rebars used in the said plate is in the same pattern as flat slabs.
- 15 07. A bracketed flat plate system the rebars in bracket are place diagonally within the beam and portion of the rebars being extended into the flanges to avoid congestion of steel at the column-bracket junction.
- 20 08. A bracketed flat plate system the plate structures are provided with lateral force resisting elements such as shear walls, core walls, braced columns to resist lateral forces due to wind and earth quake forces.

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CLAIMS

1. A Bracketed Flat Plate system comprising a concrete flat plate or slab structure for construction of office, commercial, warehouse, car parking and podium structures thus facilitating safer, economical and construction friendly approach and also using less consumables such as concrete and rebars characterized in that:
 - a. The concrete flat plate is cast in-situ;
 - b. One or more diagonal brackets are provided at the column-slab junction extending to $L/4$ - $L/5$ of spacing of columns, said brackets being tapered in depth at column-slab junction;
 - c. A depth of the bracket vary from column edge $L/9$ to $L/10$ to $L/25$ to $L/28$ at free edge;
 - d. A width of the bracket being $L/25$ to $L/28$; and
 - e. The slab thickness varies from $L/56$ to $L/54$, wherein L being the length between the center to center of columns.
2. The Bracketed Flat Plate system as claimed in Claim 1, wherein the load path in the bracket flat plate system is of one-way shear and has bending mode at the column-bracket junction resulting in different mode of transfer of forces.
3. The Bracketed Flat Plate system as claimed in Claim 1, wherein the cast in-situ flat plate is provided with the rebars or post-tensioned slabs such that quantity of rebars used is less.