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Investigating The Concept of "Strong Column-Weak Beam" in Reinforced Concrete Structures: A Literature Review

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Abstract: "Strong columns and weak beams (SCWB)" is a structural engineering principle that suggests a building's columns must be stronger than its beams. The beams should be flexible enough to deflect and absorb stresses, while the columns should be strong enough to support the load. It is intended to prevent the building as a whole from collapsing. When the column is stronger than the beams in a moment, the plastic hinges will move to the beam and prevent widespread damage. In this scenario, the only visible indicator of beam damage would be flexure, and people would have enough time to leave before the beams failed above them. This work is divided into nine main sections.

Keywords: "Strong columns and weak beams (SCWB)", flexural capacity, stresses, plastic hinges, beam damage.

1. Introduction

Over the past decades, reinforced concrete has become a global building material, and it stands to reason that natural disasters such as earthquakes cause varying degrees of damage. But what distinguishes earthquakes from other disasters is that the damage to lives is almost entirely related to man-made structures, and the damage caused by an earthquake to infrastructure leads to significant material losses and a decline in the country's economic growth [1].

In the event of an earthquake, the building's columns are crucial in preventing the structure's collapse. The column must support the gravity load of the structure and its inhabitants even if it is deformed. Most international standards recommend the "Strong Column-Weak Beam" (SCWB) design to reduce the risk of column element failure [2]. Beam (MB) flexural capacity must be precisely less than the Column element (MC) flexural capacity at any joint, as per the "Strong Column-Weak Beam" (SCWB) design philosophy. In this method, plastic hinges (which is a yielding zone in structural elements that generally develops at the point of Maximum Bending Moment, support, etc.) form in beam elements rather than in the column elements of the structure. As plastic hinges form, the earthquake's kinetic energy is dissipated, and the structure can deform inelastically. There will be enough time for people to evacuate the building. It is also preferable for plastic hinges to form in the upper storeys of the building before the lower storeys, as the former experience less force from gravity. As a result, the beam's plastic hinges allow them to withstand greater deformation without collapsing [3]. A beam failure is considered a local failure, while a column failure is viewed as a global failure. A damaged beam can be quickly repaired; however, a damaged column is much more difficult to reconstruct because it affects the structure's overall stability [4]. Fig. 1 (a) and (b) show the failure mechanism of the "Strong Column-Weak Beam"(SCWB) design building and the "Strong Beam-Weak Column" (SBWC) design building (It is a very dangerous condition because it causes sudden collapse of buildings and consequently a great loss of life and property) [5]. This paper reviews several research studies by various researchers on optimizing the behavior of earthquake-resistant buildings (SCWB). The paper is divided into nine main parts to achieve the (SCWB) condition, as mentioned below.

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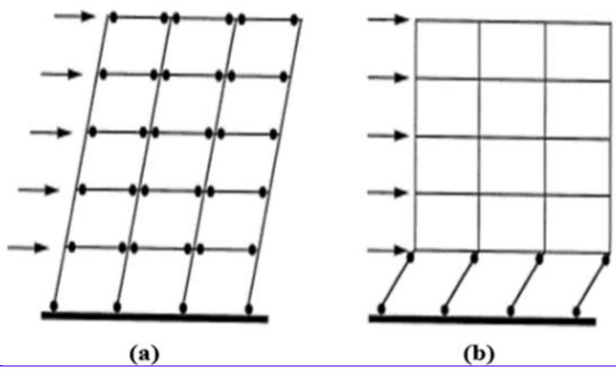

Fig.1. (a) Mechanisms of "Strong Column-Weak Beam" (SCWB) and (b)"Strong Beam-Weak Column" (SBWC) [5]

1.1. Column-to-Beam Flexural Strength(ηC).

Increasing the column's moment resistivity and flexural strength ratio(ηC) by the requirements of international codes reported in Table. 1 below, which improves the column's ductility and stability. The flexural strength ratio (ηC) is defined as the ratio of the total nominal flexural strength of the beams to the total nominal moment capacity of the columns. According to Nie et al., the flexural abilities of columns($\sum MC$) at the Beam-Column Joint (BCJ)(The BCJ can be defined as an essential part of the column that transfers the forces at the ends of the members connected to it. The members of the rigid jointed plane frame resist external forces by developing twisting moment, bending moment, axial force and shear force in the frame members), of the RC frame need to be greater compared to the beams ($\sum MB$) in the joint (BCJ) to fulfill the (SCWB) in an RC frame [6] where the relationship$\sum$MC = $\boldsymbol{\eta_C}$ $\sum$MB should be satisfied.

The term (η_C) refers to the ratio of flexural strength between the column and the beam, and it should exceed one. The (SCWB) mechanism can be abused for two reasons:

1- Beam (flexural capacities) that are underestimated in design (i.e., real flexural capacities are higher than those calculated in design).
2- The minimum value for (η_C) is insufficient. Studies relating to the (SCWB) philosophy of design have so far concentrated on these two issues: determining an appropriate (η_C) and calculating (M_B).

In order to implement the (SCWB) mechanism into the RC frame, it is crucial to determine an appropriate value for the "column to beam flexural strength ratio" (η_C).
Researchers from different countries have carried out several investigations on the calculation of (η_C) and the proposed values of (η_C).

In a study of two buildings (three and six stories) where the strength ratio varied from 0.8 to 2.4, Dooley and Bracci [7] found that as the ratio(η_C) was increased, the protection life safety of the building's occupants increased due to the decreased likelihood of a story mechanism occurring. Adjusting the column reinforcement to increase the strength ratio has a greater impact on seismic performance than increasing the members' size.

The (SCWB) strength concept is used in building codes to reduce the risk of the formation of story mechanisms. Beams forming plastic hinges under seismic loading are optimal and desirable energy dissipation methods. Column falls due to the inability to unfold physical property if plastic hinges are created at each end. This could lead to the Complete collapse of the building. The column-to-beam strength concept of 1.2 or above, as calculated at the joints, is required by the ACI 318 requirements [8]. GÖKDEMİR and GÜNAYDN [9], Using the Turkish Earthquake Code, this research examines how a different coefficient (η_C) affects moments in columns and beams. The study's findings showed specifically that:

1- The columns sustain severe damage when beams are given more strength than columns during construction, as in Figure 2. If there's no barrier between the columns, the lower edges of the columns get seriously harmed. Because story slabs remain stiffer than columns, the columns in these areas suffer damage when earthquakes happen.
2- The most important requirements for earthquake-safe buildings are that the columns be of greater strength and carry more resisting moments than the beams at the (BCJ) area. Europe, the United States, Japan, and India have all mentioned this in their seismic codes.
3- Beam plastic joint hinges can absorb and consume seismic energy if the columns are built to withstand higher force than the beams.
4- According to the Turkish Earthquake Code, the beam-column joints require a ratio of ultimate strength (β) larger than one (β = 1.2) between the top and bottom columns and the right and left beams.
5- Worldwide, earthquake codes require a coefficient(β) greater than 1.2.

Three RC frames for 5, 8, and 12 stories in height were studied by Thakur and Chand [10] for the (SCWB) concept of zone five and medium soil, with moment capacities checked under IS1893:2016[11]. The plastic hinges used in the pushover analysis of columns and beams in ETABS 2016 are tested and confirmed using the acceptance criteria specified in FEMA 356[12]. All frames are examined for basis shear as well as performance point with displacement. Research indicates that:
1- Beams that have formed plastic hinges are better able to dissipate seismic energy, which is why they are so valuable for earthquake-prone areas. A global failure occurs when a column cannot distribute its plasticity because plastic hinges have formed at both ends.
2- The performance point as well as displacement both increased with storey height, indicating the necessity for shear walls to reduce displacement and improve the building's strength.
3- The moment capacity ratio plays a significant role in enhancing a column's ductility and moment resistivity in accordance with code requirements. Table 1. Shows values of the Moment Capacity Factor used in many International Codes.

Fig. 2. Weak /column-strong/ beam failure [9].

4- The (SCWB) idea is used by all international codes, and the value of β* (beta) varies from country to country. Moment in columns must be at least as strong as beams under the code regulation.

$$\sum Mc \geq \beta \sum Mb$$

Table1. Values of the Moment Capacity Factor in many International Codes [10].

International codes	Value of β
American Standard (ACI 318M-02)	1.2
New Zealand standard (NZS 3101:1995)	1.4
European standard (NZS3101:1995)	1.4
Indian standard (IS13920:2016)	1.4
American Standard (ACI 318M-02)	1.2

*β (ratio)= flexural strength ratio(η_C)= the ratio of the total moment capacities for all columns($\sum M_c$) to that for the beams ($\sum M_b$).

Sudarsana, Budiwati, et al. [13] They looked into how a building's performance would change if the column-to-beam strength ratio were altered. fourteen- interior frame models for (2) kinds of structures were modeled and studied; these buildings had either five or ten stories. Column-to-beam strength ratios of 1.0, 1.2, 1.4, 1.6, 1.8, and 2.0 are used as the primary parameter in these models. Column nominal strength($\sum Mn_c$) & beam nominal strength ($\sum Mn_b$) were utilized to determine the results. A static non-linear pushover evaluation was conducted to compare the various models' performance. Analysis results show that:

1- Each model is assigned a life safety performance grade.
2- A collapse mechanism of the beam sway mechanism has been achieved for five-story frame models with strength ratios of 1.4 to 2.0 and ten-story frame models with strength ratios of 1.6 to 2.0.
3- A significant increase in the ductility factor can be achieved by increasing the strength ratio to 1.4. However, beyond that point, the ductility remains unaffected for both five-story and ten-story frame models.
4- In regions with high seismic activity, a strength ratio of (1.2) is insufficient to ensure that a structure meets the SCWB criteria.

1.2. The Effect of the Strength Class of Concrete on Seismic Degradation.

Various engineers and researchers have chosen to focus on High Strength Concrete (HSC). By significantly reducing the dimensions of structural elements, (HSC) effectively decreases material consumption. HSC has additional benefits compared with Normal Strength Concrete (NSC), including increased strength and durability. Despite achieving practical acceptance, the implementation of (HSC) in regions with high earthquakes lags significantly behind regions with moderate earthquakes. For instance, concerns regarding (HSC) columns, such as their strength and ductility, had not been adequately addressed before the publication of ACI318-14 [14]. However, the ACI-ASCE committee 441 reported the state of the art regarding (HSC) in 1997 [15].

In a recent study, Sococol et al. [16], The seismic response of three models of RC moment-resisting frames (GF+1F) was analyzed by nonlinear static analysis in ATENA software (for a total of three concrete strength classes and equal longitudinal & transverse reinforcements for the structural parts). Significant findings were drawn about how concrete strength class affects the mechanisms of seismic deterioration and collapse for this kind of structure (characterized by stiff RC longitudinal beams).

1- It has been discovered that the concrete's strength class has a significant impact on the occurrence of cracks, with a lesser number of cracks occurring at higher concrete classes. Furthermore, the pattern of cracking aligns consistently with the direction in which the lateral force is applied.
2- Global lateral deformation capability of the structure improves with the higher strength class.
3- A higher concrete strength class is needed in an RC frame model because of how longitudinal RC rigid beams affect the plastic hinge formation at the ends of the RC columns, which is different from how the ductile idea works. As a result, one option could be to reinforce the RC

columns more than the minimum level allowed.

Zhu et al. [17] demonstrate that High Strength Concrete (HSC) columns, equipped with multiple stirrups and structural steel ratios widely utilized in practice, have exceptional earthquake performance.

In their study, Taheria et al. [18] assessed the ductility of 112 (HSC) columns by analyzing their axial loading, volumetric ratio of the transverse reinforcement, bar arrangement, and concrete and reinforcement strengths. The findings suggested that an increase in concrete strength leads to a reduction in ductility. Nevertheless, ductile behavior could be achieved in HSC columns by ensuring appropriate confinement.

According to Kadid and Boumrkik [19], reinforced concrete failed during the Boumerdes earthquake because of the quality of the materials used and the fact that most buildings in Algeria are of the strong/beam - weak /column type.

1.3. Influence of Beam-to-Column Stiffness Ratio.

Seismic design codes for RC moment-resisting frame structures often adopt the "Strong Column-Weak Beam" (SCWB) philosophy, which allows beam plastic deformation while retaining columns elastic. Without taking into account the influence of a beam-to-column stiffness ratio upon collapse modes of global structures, (SCWB)frames are developed based on the beam-to-column flexural capacity ratio needed to secure the beam-hinge mechanism during major earthquakes. Flexural stiffness, story height, and span can all be determined by comparing the beam-to-column linear stiffness ratio [20]. The strength and flexibility of the material are defined as follows:

• Stiffness is a measure of an element's propensity to revert back to its initial shape following the application of a force. The design of tall structures requires a high level of stiffness in order to prevent collapse. This can be achieved by using elements such as shear walls, cores, and tubes.

• Strength is a measure of the maximum amount of stress that may be given to an object before it permanently deforms or breaks. Strength plays a crucial role in determining the appropriate size and materials for construction [21].

Wongpakdee1 and Leelataviwat[2] [22], The researchers examine the non-elastic response of SCWB frames with varying distributions of beam & column plastic -strengths at varied levels of ductility requirement. The 9-story midrise buildings were constructed with SCWB frames, which have equal lateral strength but varying column strength & stiffness compared to the beams. The findings of nonlinear static as well as dynamic analysis show that the relative-plastic flexural capabilities of the beams, as well as column bases, have a considerable influence on the structural deformation as well as seismic responses of (SCWB) frames. The structural reaction and beam-to-column-joint demand are significantly influenced by the column's strength and stiffness.

SU et al. [23] stated that constructions with greater beam-to-column linear stiffness have a significant rise in the level of damage to columns. This has a detrimental effect on the overall ductility and deformed capacity of the structure.

SU et al. [24] examined the impact of the ratio of linear stiffness between the beam and column on the failure mechanisms of RC frame constructions. Two scaled-down models, one-third the size of actual 3-bay, 3-story RC frames, were built and subjected to modest reversed cyclic loads. The purpose was to validate the theoretical analysis & examine how the ratio of stiffness between the beams and columns affects the failure patterns of the structure. The conclusions drawn are solely derived from the frames applied in this study and are presented as follows:

1- The structural yielding process is mostly influenced by the materials strength, section dimensions, reinforcement ratio, as well as axial compression ratio, which were identified as the most sensitive factors. The comparative rigidity of beams in relation to columns has a notable impact on the collapse mechanism of a reinforced concrete moment-resisting frame. The beam-hinge mechanism could be easily achieved when the actual ratio of linear stiffness between the beam and column was below the suggested limit values.

2- The experimental results demonstrated that the ratio of linear stiffness between the beam and column had a significant impact on the relative damages of structural elements. In structures where the ratio of stiffness between the beams and columns is higher, the plastic hinges are primarily located in the columns as well as grow at a slower rate in the beams. Structures with low beam-to-column linear stiffness ratios exhibited bigger beam-to-column damage ratios, suggesting that the beams sustained more severe damage compared to the columns. This is advantageous for allowing a beam-hinge mechanism.

3- Dynamic analysis showed that several design codes may not be sufficient to ensure SCWB seismic behavior if the relative bending strength of beams and columns is used. The structural design must take into account the stiffness ratio of beams and columns.

Mahmood1 and Mahmood[2] [25], said that Jindal examined the effects of the shear wall on the pushover study of the seismic response for a G+7 residential structure. The impacts of the shear wall's presence at three distinct sites were predicted using the displacement control pushover analysis. Plastic hinges for columns and beams were modeled in the nonlinear analysis using moment-curvature relationships. By gradually increasing the displacement at the top nodes, fulfilled the conditions for displacement control. The analytical outcomes include the pushover curve as well as hinge development. Beams were discovered to develop hinges before columns, and the greatest base shear capacity determined to be greater than the proposed base shear. Without a shear wall, the model anticipated the highest possible drift ratio. The results demonstrate that the shear walls improved the structure's lateral load resistance.

Hu et al. [26], An investigation was conducted on three single-reinforcement concrete (RC) frames, of which one was a reference specimen (S1) and the other two were specimens reinforced with shear walls (S2, S3). These frames were subjected to low cyclic loadings to assess the seismic performance of reinforced single-frame structures featuring exterior cantilevers. By comparing and analyzing the evaluated frames' degradation in strength, stiffness, hysteretic-behavior, skeleton-curve, and energy dissipation, the shear wall-based reinforcement technique for reinforcement of single frames was confirmed to be valid. According to the outcomes of the tests, the load-bearing capacities and rigidity of the reinforced frames were significantly greater than those of the reference frame. On cantilever side, the shear wall failure pattern (SCWB) was identified, with the collapse of the shear wall consistently occurring before that of the column. This characteristic has the potential to enhance the seismic performance and structural redundancy for an original single frame (Figure 3).

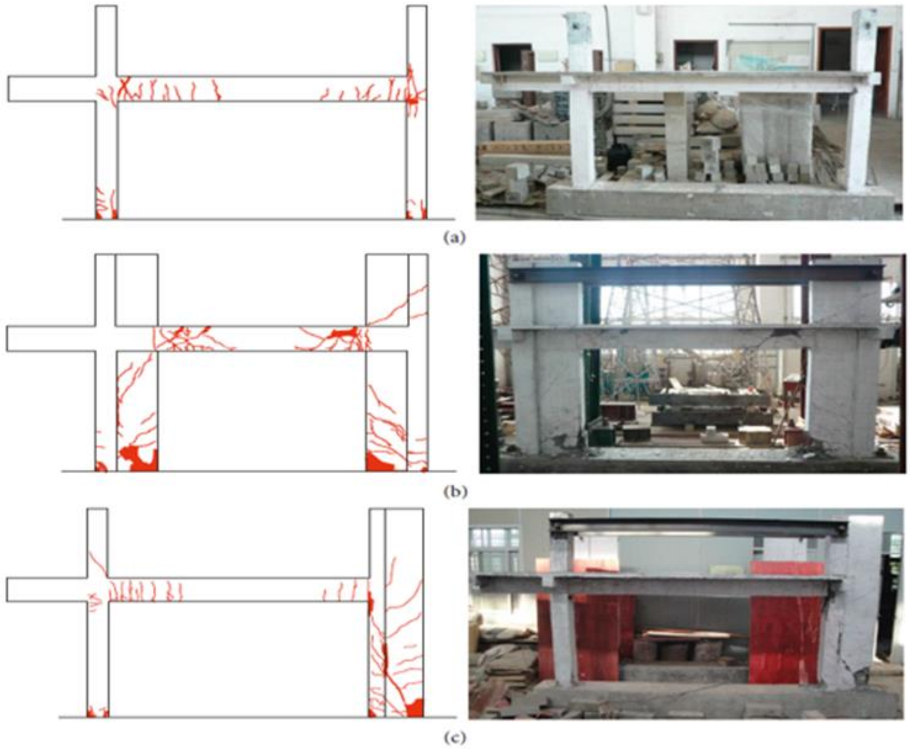

Fig. 3. Photographs showing crack patterns of test specimens: (a) specimen S1, (b) specim en S2, and (c) specimen S3 [26].

1.4. The Effect of Column Dimensions and Shape on RC frame Seismic Performance.

According to the principle of (SCWB), columns should be rigid in comparison to beams in order to prevent shear deformation of the building. The selection of a suitable shape, size, as well as the orientation of columns in a building, is crucial in determining the total stiffness of the structure. Columns not only contribute to the lateral stiffness of a building but also determine the shape of its deflection.

MURTY [27] Explained how seismic inertia forces produced at the floor levels of structures are transmitted to the ground via different beams and columns. The proper construction elements must be rendered ductile. A column failure can impact the overall stability of an entire structure, whereas a beam failure only has a localized influence. As a result, columns are less suitable for serving as ductile weak connections than beams. The term for this approach to designing RC structures is the (SCWB)design method.

Tajzadah and Agrawal [28] They researched the effect of the shape, size, and orientation of (rectangular columns) in building plans on the overall stiffness and seismic response of a building under earthquake conditions. ETABS software was used to design a 15-story reinforced concrete building with different column shapes (square and rectangular), column sizes (changing cross-sectional area along the building height), and column orientations. The goal was to determine the effect of each factor on the building's stiffness and seismic response. The conclusions of this investigation are as follows:

1- The selection of the suitable form, size, as well as orientation of columns in a building, particularly in a rectangular plan construction, is crucial in determining the general rigidity of the structure
2- Choose a rectangular column shape for structures with rectangular plans that have stronger

column sides along grids with lower dimensions. This increases the stiffness and strength of the building, which improves its base shear capacity and overturning resistance.

3- Increasing the size of the column results in an increase in both the mass and stiffness of the building model. If the percentage rise in mass due to an increase in column size is less than the percentage improvement in stiffness, a time period for the construction decreases.

Sony and Vimala [29], To enhance the lateral load strength of the structure, it is recommended to increase the proportions of the column sizes. Additionally, it was discovered that increasing the column sizes resulted in an increase in both the base shear as well as displacement. Furthermore, this increase in column sizes led to a transformation of the plastic hinges in the columns into beam hinges, hence enhancing the structural capacity. The primary disadvantage of this procedure is the need for a greater amount of materials and a larger area for the cross-section.

1.5. Impact of Different Heights on Seismic Capacity of Buildings.

In recent decades, the number of high-rise buildings has increased significantly as height has become a kind of urbanization all over the world, so people tend to build tall buildings, but as the buildings get taller, the greater their risks. safety is one of the main tributaries on which the local economy is based and occupies an important position at the level of international organizations anywhere in order to protect lives and property [30].

Irfani et al. [31], explore the collapse mechanisms of three structures of 5, 12, as well as 15 storey heights for the (SCWB) idea. The goal of this project is to assess the static(non-linear) performance of 3 different structures of differing heights. The structures are 15m, 36m, and 45m tall. The parameters acquired from the analysis include the structure's base shear, displacement, and hinge forms. The base shear as well as displacement of the buildings rise as the (SCWB) concepts increase. Low-rise building hinge formations involved beam failures, but mid-rise building hinge formations involve a mixed failure mode incorporating beams and columns.

GÖKDEMİR and GÜNAYDN [9], studied behaviour of the (SCWB) as well as (WCSB) frames under horizontal loads. they concluded the storey displacements of SCWB,are less than the WCSB condition. As shown in Fig. 4, where (δi) represent the (relative storey displacements), and (Δtop) represent the (top displacements) of the frame.

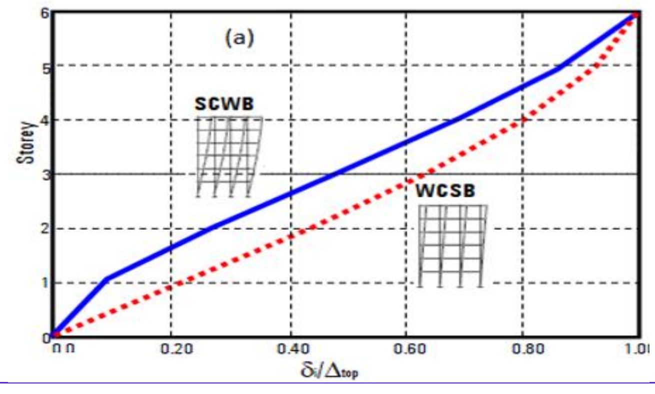

Fig. 4. Storey displacements of (SCWB) as well as (WCSB) conditions [9].

Khan and Vyawahare [32], say that as the soft storey progresses to higher levels, the intensity of hinge creation decreases while displacement increases and base shear increases.

Priyanka and Mayur [33], investigated the sway mechanism as the primary cause of failure of multi-story RC frames during earthquakes. It indicates that if a frame is developed using the (SCWB) idea, the possibility of collapse owing to sway mechanisms is fully eliminated. This can be accomplished in a multi-story frame by enabling plastic hinges to form in a preset sequence just at the ends of all beams while columns stay essentially elastic and by preventing shear mode of failure in beams and columns.

Kim et al. [34]. Call Outriggers are a most frequent system to control the lateral drift for high-rise structures. Outriggers are oriented horizontally trusses, beams, or wall elements which connect a core to an exterior column to reduce lateral movement and increase lateral stiffness, as shown in Figure 4. When lateral loads occur, the outriggers minimize the overturning moment created in the core of the shear wall and convey the decreased moment to the exterior columns.

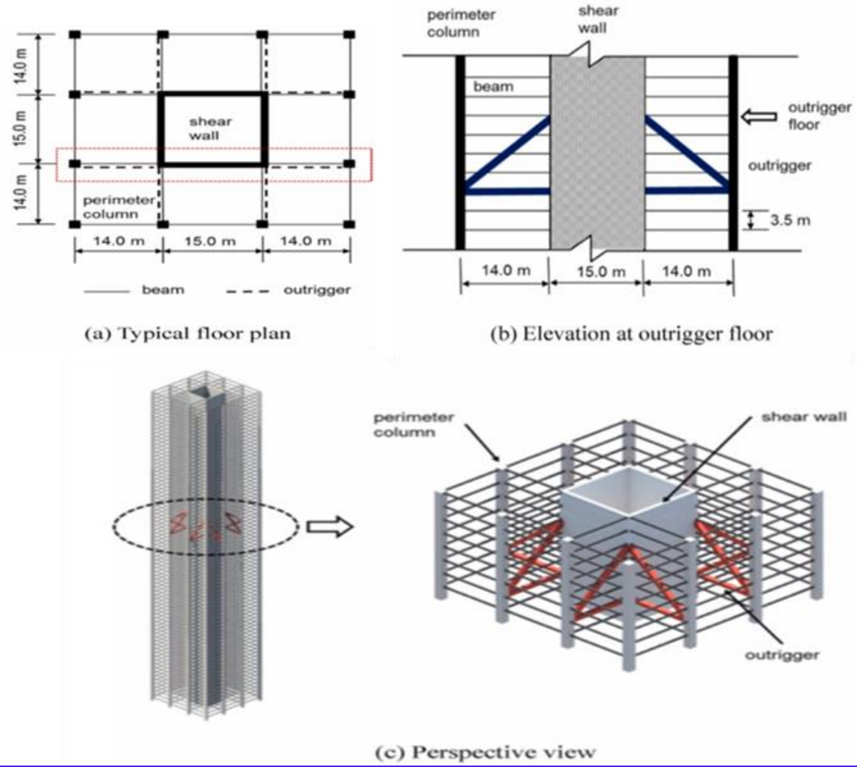

Fig. 4. Outrigger configuration and analysis models.

1.6. The Impact of Soft Storey upon RC frame Seismic Performance.

Many buildings collapsed during the earthquake due to soft storey it behaves exactly opposite, "Strong Beam -Weak Column"(SBWC) behavior, which means columns failed before the beams yielded, as shown in Figure 5. This is because the fundamental design concept of earthquake resistance design of structures is to make (SCWB) construction to ensure safety. Soft-story buildings are especially dangerous because of the havoc they may cause when an earthquake strikes [35].

Fig. 5. Seismic Buildings with Open Ground Storeys - RC frame structures with open ground storeys collapsed after 2001 (Bhuj in India) Earthquake [27].

A soft storey, also known as a weak storey, is a story in a construction that has insufficient rigidity or ductility to withstand an earthquake. The soft story is a large open space storey.

According to Sardiwal et al. [36], the building of open-ground storeys is extremely risky if not constructed properly and with care. A typical soft storey building is a three-story apartment building with huge openings on the ground level, like a garage for cars or a series of retail establishments with large windows. This sort of irregularity is caused by a sudden decrease in stiffness or strength within a specific storey. In an active seismic zone region, irregularity in construction may be a significant difficulty to a qualified structural engineer.

Deshpande and Bhalchandra [37] They investigate the behavior of different models of the identical moment-resistant frame structure with an open first storey and unreinforced masonry infills in the higher floors. The structural activity of upper-story masonry infill panels was taken into consideration via simulating them as (equivalent diagonal struts). Essential natural periods, stiffness of the open first storey in respect to the higher storey, lateral displacements, and inter-storey drift via linear elastic analysis utilizing the ETABS analysis tool are among the parameters examined. It has been shown that a large difference in stiffness within the soft and upper storeys is responsible for raising strength demand on first-floor columns.

Paidalwar and Awchat [38] The researchers are examining the behavior of the ground floor storey's infill due to an increase in storey height. The presence of a soft storey is a significant contributing factor to structure damage during an earthquake, as consistently indicated in all investigative reports. The concept of a soft storey, resulting from an increase in the height of a storey, is a widely recognized topic. Variations in the number of infill walls between different levels also lead to the occurrence of a soft story. Typically, these are not regarded as components of the load-bearing system.

Sheet et al. [39] They said "Fiber Reinforced Polymer (FRP)" jackets for columns had shear and flexural reinforcement to prevent shear failure and reduce inter-storey drift. FRP jackets increase the strength, ductility of a structure while maintaining component rigidity.

1.7. The Effect of "Cast-in-Place Floor Slabs.

The effect of the "Cast-in-Place Floor Slab" on the "flexural capacity of reinforced concrete beams" has been studied more than any other factor. The combination of a "Cast-in-Place Floor Slab" and the "rectangular beam creates a T-section beam", where the beam acts as the web and the slabs act as the flange. This arrangement dramatically improves the beam's ability to resist bending and increases its flexural capacity.

Leon [40] conducted an experiment using two different specimens: one with the "column-beam joint" but no slab, additional one with the "column-beam joint" and a slab. The purpose of the experiment was to investigate the impact of a "Cast-in-Place Floor Slab" upon the performance of joints. The outcomes of the tests indicated that addition of a "Cast-in-Place Floor Slab" significantly influenced the level of strength & behaviour of the joints. Specifically, in the junction without a slab, plastic- hinges formed mostly at the beam ends, whereas, in the joint with a slab, plastic- hinges formed primarily at the column ends.

Ning, Qu, et al. [41] evaluated two 2-story RC frames at a scale (2/3), one of which featured "cast-in-place floor slabs" as well as the other that did not. The examination outcomes indicated that the RC frame lacking slabs exhibited a beam-sway mechanism due to the influence of the "cast-in-place floor slabs ". In contrast, the frame with slabs transitioned to a story-sway mechanism.

1.8. The Influence of Infill Walls.

RC frames with masonry infills are a popular type of high-rise building construction in urban regions. The term infilled frame refers to a composite building created by combining the moment-resisting-plane frame and infill walls. Infill walls change the behaviour of frame action into truss action, changing the lateral load transfer mechanism.

The researchers Ye et al. [42] examined RC frames that were affected by the "2008 Wenchuan earthquake in China " as well as analyzed the elements that contributed to the failure of the (SCWB) mechanism. The impact of infill-walls, which were inadequately accounted for in the structural design, was identified as one of the primary factors. Typically, in actual structures, infill walls are positioned directly on the beams, resulting in the following consequences.

1- Infill walls can lessen the beam's deformation and improve the beam's stiffness and flexural capacity.
2- Infill walls play a role in the seismic behavior of the entire structure by enhancing the rigidity of the floors where they are present. This creates an uneven distribution of stiffness throughout the structure, with the floors containing infill walls being stiffer than those without. Consequently, the floors without infill walls, typically the ground floor, become weaker layers, leading to the development of a swaying mechanism at the ground level. Additionally, the presence of infill walls causes (irregular distribution) of stiffness in the structural plane and introduces a torsional effect.

Shi [43] experimented on two RC frames. First was a pure frame, while the second incorporated infill-walls. Shi performed "elastic-plastic time history finite element" calculations on these two frames using "PERFORM-3D,2011". Each of the experimental tests & (numerical simulations) demonstrated that infill-walls have a substantial impact on the inner force distribution within a structure, resulting in increased bending moments at ends of columns. This phenomenon can cause columns to fail before beams.

Three different 4-story, 5-by-3-span RC frame models were subjected to pushover assessments by Fiore et al. [44]; one was a pure frame, another had infill walls on all floors save the ground, and the third had infill walls on all floors except the ground. According to the findings of the study, the RC frame's failure process could be altered by the addition of infill walls.

Wakchaure and Ped [45] discovered that the displacement of the top story of a high-rise building is reduced. Base shear has been increased because of the use of infill walls. Adding non-structural/masonry/ infill walls aids in the seismic performance of an RC frame High Rise building.

1.9-Beam Column Joints.

The most crucial zone in an RC moment-resistant frame is the beam-column joint. During an earthquake, it is subjected to tremendous forces, so its behaviour has a significant impact on the overall structure's response. As a result, careful attention must be made to the detailing of such a joint. Murty et al, say that beam-column connections within moment frames are considered to be unique. As illustrated in Fig.6, these are sections of columns that are shared by beams in RC structures. These sections are composed of constituent materials with limited strength, and as a result, the joints' force-carrying capacity is restricted. When seismic forces exceed these magnitudes, joints sustain significant damage. It is difficult to repair damaged joints; therefore, damage must be prevented; beam-column joints have to be meticulously designed to withstand the effects of earthquakes [46].

Hanson and Connor [47] conducted a series of tests on the seismic performance of Beam/Column Joints (BCJs) that served as a reference for further research. Their test results revealed that the concrete component bears the majority of the shear force of a joint, and the confinement of concrete is related to the transverse stirrups; hence, the concrete does not provide considerable shear resistance to the joint.

According to Subramanian and Rao [48], the opposite direction of forces in beam-column junctions during earthquakes might cause distress and failure if not adequately designed and documented.

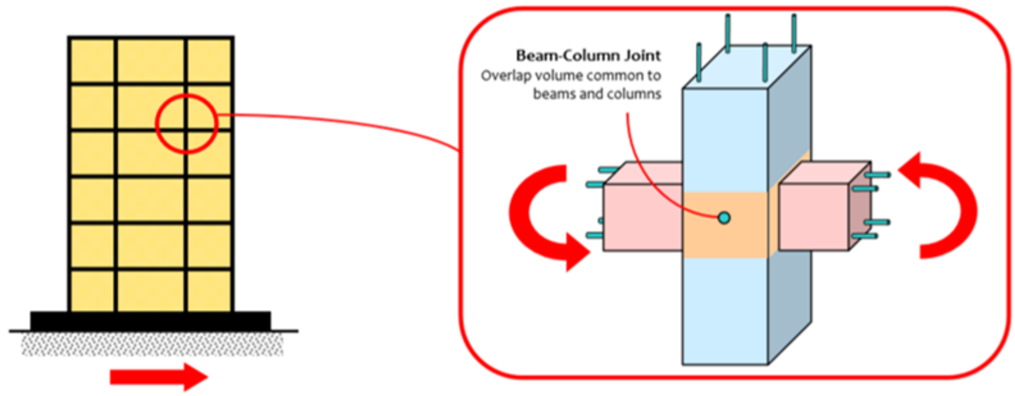

Fig. 6. Beam-Column Joints in Construction: These are critical sections of a structure and must be designed [46].

Krishnan and Ramtekkar [49] Say that the joint core of the beam and column is a critical area in the RC moment-resistant frame. The performance of these joints significantly impacts the structural integrity and flexibility of the entire frame. Beam/ column joints are crucial regions in frames built to withstand severe seismic activity with inelastic response.

Meinheit and Jirsa [50] proposed that the primary factor contributing to the shear strength of a joint is the formation of a diagonal /compression strut- mechanism within the joint. They further argued that the shear strength is governed by the cross-sectional area of the joint.

According to Calvi et al. [51], They found that the T-shape joint experienced damage as a result of rebar slippage as well as shear failure of hook caused by stress concentration. This damage led to a significant reduction in both strength and ductility. The study determined that the utilization of hooks as well as anchorages in the joint enhances the seismic capacity.

According to the ACI-ASCE Committee 318, 2011[52], ductile structures should have joints designed based on the SCWB concept, where the width of the column is either equal to or larger than the width of the beam.

In a study by Sharma and Bansal [53], the seismic performance of RC frame constructions is greatly impacted by the quality of their beam /column joints. Damage from non-linear rotation is exacerbated by the lack of ductile detailing of joints between RC beams and columns in buildings constructed before earthquakes. Strengthening the damaged beam-column joint is made easier with the retrofitting method, which also improves the load-bearing capacity, energy dissipation, as well as ductility of the (BCJ) in comparison to the control specimen.

Yu et al. [54] studied the seismic behavior of nine full-scale /reinforced concrete joints, eight precast RC joints, and one cast-in-place RC junction under cyclic loading. They concluded that raising the concrete /compressive strength as well as a larger rebar diameter in the joint core region can boost joint stiffness to a certain amount.

According to Shen et al. [55], horizontal stirrups are typically necessary for RC beam/column junctions (BCJs) to withstand shear stresses in seismic design. In order to withstand a significant lateral load, RC moment-resisting frames require a substantial quantity of stirrups in the joint cores. This may result in the accumulation of additional load-bearing stress, leading to challenges in construction and inadequate consolidation of concrete, ultimately resulting in suboptimal seismic performance. He proposed a new reinforcing detail for RC inside (BCJs), which involves using unbonded diagonal bars that are mechanically fixed at the ends of the beam. The inclusion of this specific feature helps to reduce the overcrowding of reinforcement by partially substituting horizontal stirrups. Additionally, it enhances the seismic performance of (BCJs) by relocating plastic hinges and reducing the input shear force as shown in Fig.7. Four RC interior (BCJ) specimens, scaled down to 2/3 of their original size, were fabricated and subjected to quasi-static cycle loading. Among these specimens, one was designed according to the present code, while the remaining three specimens incorporated the suggested reinforcing detail. The test findings demonstrate that the suggested reinforcement detail effectively moves the plastic hinges away from the interfaces between beams and joints. Additionally, it enhances the stiffness, energy dissipation capacity, loading capacity, and bonding condition of the beam reinforcements within the cores of (BCJs). Using both stirrups and the suggested reinforcement detail greatly improves the resistance to cracking and minimizes distortion in the joints. However, the inclusion of more stirrups only leads to a slight enhancement. Substituting horizontal stirrups with suggested reinforcement details in (BCJs) can reduce the overcrowding of reinforcement within the joint core. Nevertheless, traditional stirrups remain essential for containing the joint cores and counteracting shear pressures in (BCJs) when using the suggested reinforcement detail.

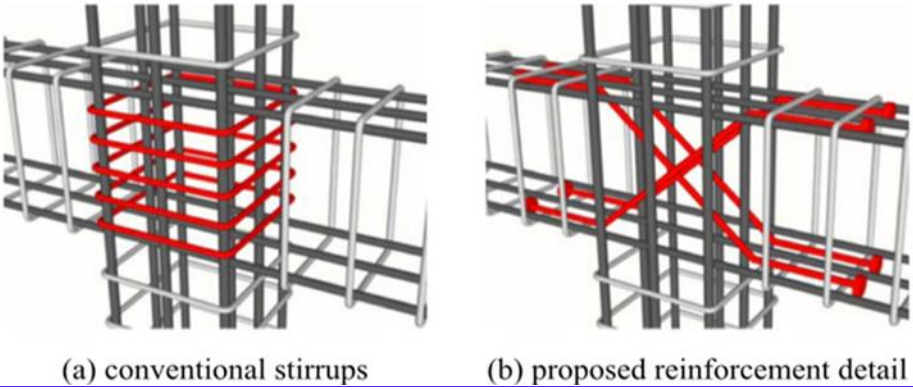

Fig. 7. displays the conventional stirrups & the suggested reinforcement detail of a reinforced concrete beam-column joint [55].

Summary:

After reviewing the most important previous studies in detail and research on the SCWB philosophy, it is essential to summarize the most significant points that affect the behavior of the building while subjected to lateral pushover forces due to earthquakes:

1- The "Strong Column-Weak Beam" (SCWB) idea has been extensively accepted as one of the primary design requirements in RC structure seismic design.

2- The column failure can impair the overall stability of the structure, whereas the failure of a beam has a limited effect.

3- In order to get the "Strong Column-Weak Beam" (SCWB) behavior in a (RC) frame, it is necessary satisfy relationship ($\sum MC = \eta C \sum M$B), where ηC represents "the column-to-beam flexural strength ratio" which must exceed a value of one.

4- Modifying the column reinforcement to increase the strength ratio was more effective for seismic performance than modifying the member dimension.

5- Using a higher strength class enhances the overall ability of the structure to resist lateral displacement.

6- Increasing the strength of concrete (HSC) reduces its ductility. However, it is still possible to achieve ductile behaviour in (HSC) columns by applying appropriate confinement.

7- High Strength Concrete-(HSC)-columns with many stirrups and routinely used structural steel ratios showed good earthquake behaviour.

8- In structures where the ratio of stiffness between the beams and columns is higher, the formation of plastic hinges is mainly localized in the columns as well as progresses at a slower rate in the beams.

9- By increasing column size, base shear, as well as displacement, are enhanced, and the creation of plastic hinges of a column is changed to beam-hinges, enhancing structural capacity.

10- Changing the size of columns in low to mid-rise- structures (up to Fifteen stories) has a detrimental impact on the seismic- performance of the construction.

11- The structures collapsed after the earthquake due to a soft storey, which exhibited the reverse behaviour of the (SBWC). This indicates that the columns collapsed before the beams yielded.

12- Determining the ideal location for soft levels in high-rise buildings. As the soft storey rises in level, the degree of hinge creation decreases, while displacement and base shear increase.

13- The existence of a cast-in-place floor slab had a major impact on the durability and performance of the joints.

14- Beam stiffness, flexural capacity, and deformation can all be improved by including infill walls.

15- Infill walls enhance the building's seismic resilience.

16- Infill walls would result in "an irregular- distribution of the stiffness" of the structure, leading to a torsional effect.

17- The beam-column joint is considered the most critical area in an RC moment-resistant frame. The structure experiences significant forces during an earthquake, and its behaviour significantly affects the overall behaviour of the entire structure.

Conclusion:

Natural disasters such as earthquakes result in varying degrees of damage to buildings. But what distinguishes earthquakes from other disasters is that the damage to lives is almost entirely related to man-made structures, and the damage caused by an earthquake to infrastructure leads to significant material losses and a decline in the country's economic growth."Strong columns and weak beams (SCWB)" is a structural engineering principle that suggests a building's columns must be stronger than its beams. The beams should be flexible enough to deflect and absorb stresses, while the columns should be strong enough to support the load. It is intended to prevent the building as a whole from collapsing. When the column is stronger than the beams in a moment, the plastic hinges will move to the beam and prevent widespread damage. In this scenario, the only visible indicator of beam damage would be flexure, and people would have enough time to leave before the beams failed above them.

Most international standards recommend the "Strong Column-Weak Beam" (SCWB) design to reduce the risk of earthquakes. This paper provides a comprehensive analysis of the existing collection of studies about the "strong column–weak beam" (SCWB) design philosophy, which has gained significant popularity in the seismic design of constructions. The paper is partitioned into nine primary sections to get the state of subjective well-being (SCWB). This article presents a review of the (SCWB) philosophy, including the definition of (SCWB), factors influencing the calculation of beam flexural capacity, the identification of a "column-to-beam flexural strength ratio" (ηC), and the negative effect of the soft storey on the buildings, which exhibited the reverse behaviour of the (SCWB). at last, the (BCJ) is considered the most critical area in an RC moment-resistant frame. Where the structure experiences significant lateral forces during an earthquake, and its behaviour may significantly change from (SBWC) to (SCWB), in case strengthen the (BCJ)area well, the overall behaviour of the entire structure improves.

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