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A METHODS FOR STRENGTHENING OF PRE-ENGINEERED BUILDING USING MILD STEEL SECTION

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Abstract: Since 1960 pre-engineered building is mostly used in industrial purpose due to many advantages. Maintenance of pre -engineered building is required due to many purposes like varying load condition etc. In this discussion about the methods of strengthening of steel structure i.e. pre-engineered building is done. Various methods are used to increase the load carrying capacity of existing steel member out of them 1) Bonding FRP sheets 2) Welding mild steel plates, are mostly adopted. Among these two mild steel plates is commonly used because of cheap cost & uniform material properties. The analysis of existing & advanced structure was carried out and compared to highlight dynamic response. The analysis was carried out on different software like STAAD PRO, ETABS, SOFISTIK, ABAQUS. We came to know that how steel cover plate length effect on load carrying capacity. Major authors mainly focus on deformed shape & stress distribution. Methods for strengthening structures include additional pre-stressing, increasing cross-section, adding elements to the cross-sectional area, reinforcing the tension zone, and using bonded steel plates. The strengthening techniques discussed in this paper will distribute stress evenly among the structure & reduce deflection which will cause increase in load carrying capacity of the members. The main objective of this paper to study Economically, practically possible and most suitable strengthening techniques are studied.

***IndexTerms* - pre-engineered building, analysis, stress distribution, deflection, strengthening techniques, existing structure**.

I. INTRODUCTION

In the modern construction industry, the concept of Pre-Engineered Buildings (PEBs) has emerged as a popular and efficient method for creating industrial structures. This trend has gained significant traction in recent years, especially in India, where major construction projects are now adopting this innovative approach. Despite its growing popularity, it is important to note that the use of PEBs dates back to the 1960s, highlighting its enduring relevance and effectiveness in building design and construction. PEBs offer several advantages over traditional construction methods, including cost-effectiveness, faster construction timelines, and superior quality control. By utilizing standardized components that are fabricated off-site and then assembled on-site, PEBs can significantly reduce construction time and labor costs while ensuring structural integrity and durability.As India continues to witness rapid industrial growth and infrastructure development, the adoption of PEBs is poised to play a crucial role in meeting the evolving demands of the construction sector. With its proven track record and numerous benefits, PEB technology is expected to remain a cornerstone of modern construction practices for years to come.
Pre-engineered buildings are characterized by the manufacturing of their components in a controlled environment at the company's facility, followed by their efficient assembly on the site. This manufacturing process ensures that the components are built with precise accuracy, minimizing defects during the assembly phase. The use of steel in pre-engineered buildings offers various advantages, such as lighter weight 25-30% lighter than traditional steel structures, superior design flexibility, and structural resilience due to steel's inherent elasticity.

II. LITERATURE REVIEW

Numerous investigators have conducted substantial research on a method for strengthening of pre-engineered building using mild steel section.

C. Maraveas et al{1}: A wind-induced failure analysis of an existing steel structure in Syros, Greece is done by author C. MARAVEAS. The structure, originally built in the 1970s as a boat shelter, now serves as an athletic centre. Due to its proximity to the sea, where wind speeds can be high, the structure faces challenges. The study first presents the wind-induced failure analysis, highlighting a domino effect starting with a corroded bracing that buckled under wind load. This led to a reduction in vertical load carrying capacity was about 42% and created asymmetry under horizontal loading, ultimately causing the failure of several other steel members. Proposed retrofitting and strengthening methods was discussed in the paper. The second part was about proposed methods for retrofitting and strengthening structures to enhance vertical load carrying capacity under wind loads. The survey identified issues such as extended buckling deformation, corrosion effects in column-baseplate connections, inadequate stiffener thicknesses, relaxed bolted connections, and minimal torsional stiffness. To address these challenges, the author C. MARAVEAS employed various numerical procedures tailored to specific investigative goals. Five simulations was carried out, namely: linear static analysis, linear dynamic modal analysis, non-linear dynamic time-history analysis, non-linear incremental static pushover analysis, and non-linear buckling analysis. The first two linear analyses was conducted using STAAD Pro, third & fourth was done by SOFISTIK software.

After performing transient time history analysis random wind histories are generated using sofistik software by sofiload module. The predictable relationship of fluctuating wind fields was taken into account by author C.MARAVEAS. The non-linear material properties of s235 structural steel was simulated for critical member such as the vertical bracing along the Y direction. The stiffness & resistance in compression was calculated for each member. The stiffness & bending in shear are negligible when compared to axial ones. An incremental non-linear static analysis pushover was performed by author to know the bearing capacity of structure. The material properties defined for the time history analysis was applied alongside the displacement shape vector form the first step of the time history analysis instead of using a fundamental eigenmode of the structure. The target lateral forces was define accordingly to wind load pattern. Effective wavelength, was defined with wind profile & effective frequency of the turbulence. Obtained response of the damaged vertical bracing to the 10 min wind time history analysis, the buckling capacity was estimated in a more precise manner via a detailed finite element simulation.

The structure was reinforced with horizontal X-bracings, vertical bracings, and strengthened vertical elements at the end of the IPE360 column. Insufficient vertical bracings was replaced, and distorted members like H type connecting beams were also replaced. The main chords of the lattice roof was reinforced using thin-walled hollow sections, and specific truss members was strengthened with second angle sections. To achieve accurate structural behaviour non-linear analysis was carried out. A strengthening proposal was developed for existing structure then existing & advanced structure are compared to highlight dynamic response enhancement +45% is presented. The load capacity curves from pushover analysis clears the increased load bearing capacity of structure.

Dr. N. M. Yossef et al {2}: An experimental behaviour of strengthening steel beams was done by conducting full-scale tests on six specimens reinforced with steel cover plates by author DR. N. M. YOSSEF .

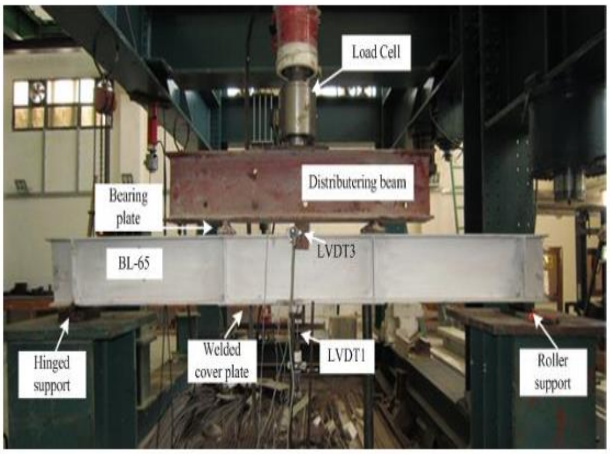

Fig. (1) Test setup for tested beam

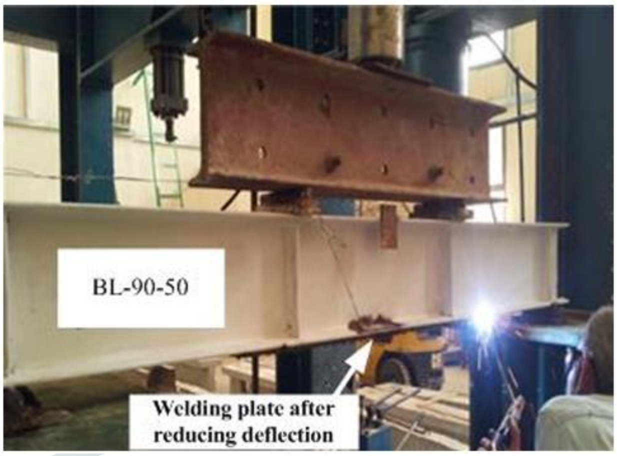

Fig. (2) Welding process during loading of specimen

The tested beam was strengthen by steel cover plate of size 8 x 0.6 cm with weld size 6 mm , two strengthen pattern was used A] cover plate at lower side(BL-90) B] cover plate provided at upper & lower side(BLU-45). While loading procedure & welded technique used for beam strengthen while loaded 1) the load was applied to certain value 2) part of beam deflection was reduced manually & measured 3) The strengthening cover plate was welded 4) Load was continued up to failure. The test result were analysed using three parameter : Welded cover plate length , strengthening pattern , preload ratio. The increase in load carrying capacity is directly proportional to increase in cover plate length. The study shows that strengthening both upper and lower flanges in the BLU-45, Pattern B specimen resulted in a higher ultimate load capacity compared to only strengthening the lower flange in the BL-90, Pattern A specimen. Additionally, the elastic stiffness of the BLU-45, Pattern B specimen was greater than that of the BL-90, Pattern A specimen. The research findings emphasize the impact of welding technique on the structural performance of reinforced beams, highlighting that reducing deflection before welding the cover plate can lead to a 2.58% to 5.6% increase in load capacity. As increase in the ultimate capacity of the strengthened specimen was 2.8% & 5.6% for preload ratio of 30% & 50%. From load deflection curve the decrease in the deflection by 30% to 42% when preload ratio is increased by 30% to 50%. Moreover, the experimental results reveal that the ultimate load capacities of the beams studied was influenced by the length of the cover plate. Specifically, the effect of the cover plate length was more pronounced when the cover plate area is smaller than the flange area, with an increase in ultimate capacity ranging from 1% to 5% associated with an increase in the welded cover plate length from 36% to 50%. The author DR. N. M. YOSSEF found that using a welding technique to weld cover plates while under load effectively increased the load capacity by up to 5.7% and reduced the maximum deflection by 30.7%.

Strengthening existing structures is a common method to prevent failure resulting from changes in function or construction errors. Currently, two techniques was commonly used to enhance or restore the load capacity of steel structures: bonding FRP sheets and welding steel plates.

Adrian Ivan et al {3}: A analysis of a steel connection was done by using solid finite element and compares it to experimental testing. Authors ADRIAN IVAN mainly focus on the deformed shape and stress distribution revealed by the analysis. Methods for strengthening structures include additional pre-stressing, increasing cross-section, adding elements to the cross-sectional area, reinforcing the tension zone, and using bonded steel plates. The bond between additional & existing steel element was achieved by easily by bolting & welding. The deterioration process, their causes & the counter measures to remove to their action & the methods to repair damages that they causes are studied. The analysis was performed using solid finite element and compared to the experimental test performed in the laboratory. Special attention was given to the deformed shape and stress distribution revealed by the finite element analysis during analysis. The methods suggested for strengthening structures include: Additional pre-stressing, Increasing the cross-sectional area, Additional elements on the cross transversal section, Additional reinforcement in the tension zone, Addition of bonded steel plates, and Adding new members without removing existing ones is also a convenient solution for strengthening steel structures. Bonding steel plates to existing structures can be achieved through welding or bolting.

Do rota Koschmidder et al {4}: Term "strengthening" refers to adding structural material to improve stability, member resistance, or stiffness. This can be done by increasing load capacity, stiffening the member, or adding restraint to enhance resistance and reduce susceptibility to buckling. New element may be added to assist an existing one in resisting design action , in such a case jacking & load transfers are required. Some strengthening techniques was recommended by author DO ROTA KOSHMIDDER was mentioned below & those was based upon load carrying capacity, stiffness, safety of member.

1)A common means of strengthening steel beams or columns is bolting on new steel sections. If load sharing is required, it may be necessary to jack or prop the existing member and use preloaded bolts to avoid slip under loading.

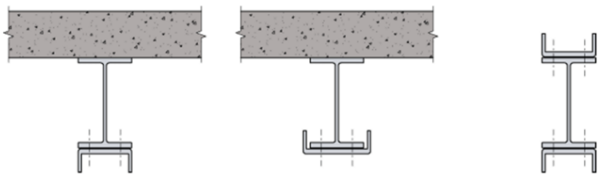

Fig. (3) Strengthening of existing members by bolting on new section

2) Welding was also be used if the original material is weld able. A wide variety of steel sections such as plates, angles or bars may be added to the basic section profile. When a strengthening plate is expected to take a significant amount of stress, it may be worth continuing the reinforcement over the full length of the member. This approach eliminates the need to consider load transfer into the strengthening plate at its ends.

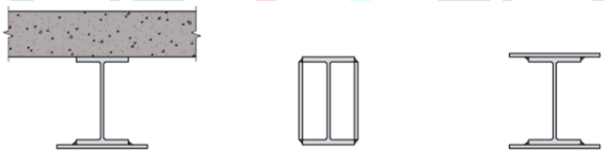

Fig. (4) Strengthening of existing members with the use of welding

3) Strengthening a steel beam was also achieved by adding shear connectors and providing either a new concrete slab or a new topping over an existing slab of weak concrete.

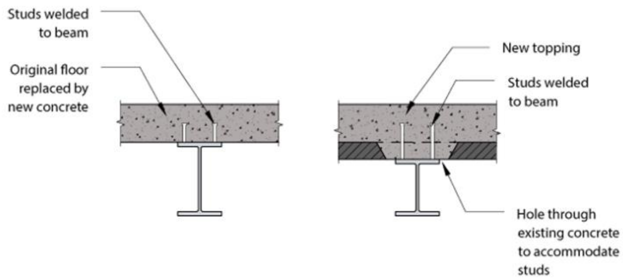

Fig. (5) Steel beam strengthened by the introduction of composite action with the new concrete

In New elements was added to assist an existing one in resisting design actions. In such cases, jacking and load transfer may be necessary. Concrete easement is a popular strengthening or stiffening technique, concrete cover of at last 75 mm was recommended to provide room for reinforcement and adequate space for concrete to flow around the member. The designer should recognize that adding a new member can alter the structural behavior of the entire system. For instance, adding a tie to an unbraced arch can greatly impact stress distribution. This discussion considers methods for creating new connections and improving existing ones to strengthen, stiffen, or stabilize existing structures.

Kamal Sh. Mahmoud, et al {5}: In this Author KAMAL SH. MOHAMMED six I-section steel beams was fabricated and tested to explore the impact of prestressing strands on the load-deflection behavior of steel beams. Five beams was reinforced with two low relaxation seven-wire strands. Experimental results showed that the load-deflection curves of reinforced beams was more rigid compared to a reference beam. The degree of stiffening in reinforced beams increased as eccentricity positions changed from 0 to 96 mm. The essential characteristics of steel material include durability, tensile strength, high strength, uniformity, toughness, performance, yielding, conductivity, and homogeneity.

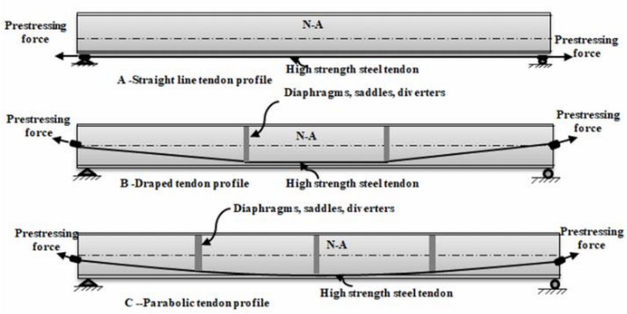

Fig. (6) Strengthening by external high strength steel strands

Prestressing is a valuable technique to create internal stresses in structural elements, balancing external loads to enhance durability and performance. External prestressing was a post-tension method used to strengthen and rehabilitate old structures like bridges and buildings. By placing prestressing strands on the outside of a structural section and transferring the force to the structural sections through diverters and anchorages plates, the method increases the stiffness of load deflection curves.

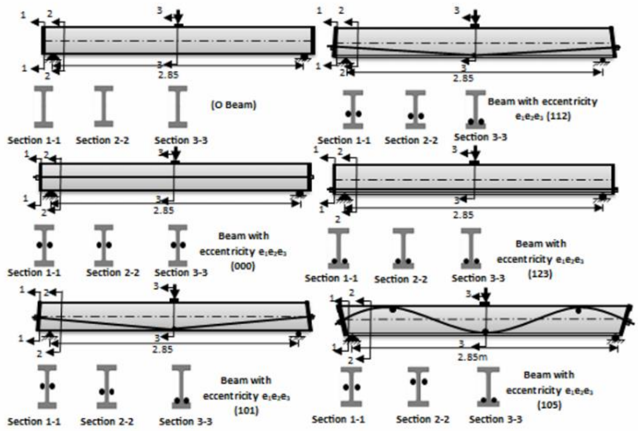

Fig. (7) Description of tested beams

The percentage of stiffening in load-deflection curves increases with higher eccentricity values, leading to a maximum percentage increase of 61.73% in the OM104 sample compared to the reference. Additionally, the percentage increase in deflection at the middle span of strengthened specimens decreases with higher strand eccentricity. The maximum percentage of decreasing at the middle span of strengthened specimens reaches to 36.31% in OM112 beam as compared with the reference. Quarter span to middle span deflection ratio is linearly with average value about 0.493 for strengthened tested beams.

M. Adil Dar, et al {6}: Cold-formed steel (CFS) was promising for rapid and durable construction worldwide. CFS beams with corrugated webs resist web buckling better than traditional I-sections. However, global imperfections can significantly impact CFS members' performance. Author M. ADIL DAR examines the effect of global imperfections on the structural efficiency of various strengthening methods in CFS beams with corrugated webs. Different strengthening techniques were applied to beams with differing levels of imperfections to assess their strength and stiffness characteristics. Six tests was conducted with simply supported end conditions, under four-point loading. The investigation focused on the load vs. mid-span displacement response, failure loads, and modes of failure of the test specimens. These results aim to fill gaps in experimental data and aid in developing numerical models for further studies and the creation of necessary guidelines. Strengthening schemes was found to significantly enhance member performance in terms of strength and stiffness, offering an efficient and time-saving solution to practical structural engineering challenges. Local and global strengthening schemes enhance the strength, stiffness, and ductility of CFS beams with corrugated webs and large global imperfections. Local schemes can increase strength by up to 113%, stiffness by up to 30%, and ductility ratio by up to 177%. Global schemes, on the other hand, show improvements of 245% in strength, 62% in stiffness, and 225% in ductility ratio for curved beams. The significant enhancement in the load-carrying capacity of reinforced curved CFS beams demonstrates the effectiveness of strengthening methods without requiring new structural elements. These strengthening techniques offer cost-effective and time-saving solutions for practical applications. By improving load capacity and reducing deflections, these schemes meet serviceability standards effectively. The spacing and arrangement of bolts are crucial for providing composite action, especially for local strengthening.

Mei Liu, et al {7}: The thread-fixed one-sided bolt was cost-effective and easy to install in engineering applications. To prevent premature thread failure, Author MEI LIU study introduces two new internal strengthening structures for the connection between the beam and hollow square column endplate. Experimental tests with six specimens under static bending moments were conducted to analyze the structural performance and efficiency of the strengthening structures. Results show that the double H-shaped stiffener enhances the yielding bending moment of the connection better than the polygonal steel tube stiffener. Utilizing strengthening structures moderately can prevent bolt hole threads failure and column wall yielding failure simultaneously, meeting the design criteria of a "strong column - weak beam" connection. Calculation methods was proposed based on test results and theoretical analysis to predict the yielding bending moment capacity of the strengthened connection, with calculated results aligning well with test results. The static experimental investigation on the Thread-fixed One-side Bolted Endplate Connection (TFOSBEC) for a steel beam to a Hollow Square Column (HSC). Two novel strengthening structures with different cross-sections were applied to the internal of the column to improve the structural performance of the connection. Test results of the strengthened connection was presented and discussed in terms of failure modes and mechanical performance. And the following conclusions are summarized: During the test, author MEI LIU observed four common failure modes: hole thread failure, column wall yielding failure, endplate yielding failure, and beam flange and web buckling. The TFOSBECs in the test experienced combined failure modes, influenced by factors such as endplate thickness, type of strengthening structure, and sidewall/flange thickness of the strengthening structure. Utilizing strengthening structure would significantly improve the structural performance of TFOSBEC by enhancing the length of hole threads and the resistance capacity of the column wall. This approach was prevented both hole threads failure and column wall yielding failure. The study suggests that the proposed calculation methods for predicting the yielding moment capacity of strengthened TFOSBEC align well with test results. This indicates the potential usefulness of the design methods put forth in the paper for the design of strengthened TFOSBEC.

Konstantinos Daniel Tsavdaridis et al {8}: Researcher KONSTANTINOS DANIEL TSAVDARIDIS efforts focused on expanding seismic strengthening options for steel buildings, citing select projects. Structural strengthening and ensuring seismic resilience in steel buildings, particularly for heavy structures with high dead loads, was crucial in increasing lateral seismic loads. Diagonal bracing must be capable of withstanding both tension and compression loads. Bolted or welded connections should have a higher tension resistance than the brace's ultimate tension value or design load. Some strengthening techniques was categorized as follows: Welding to reinforce beams by enlarging sections with plates, Strengthening connections by using seated angles, high-strength fasteners, converting single to double-shear connections, adding angles or plates, adding web stiffener plates, steel cover plates, enhancing column splices, enhancing braced frame connections, adding diagonal braces to beams, columns, girders, steel braced frames, and steel plate walls , Post-tensioning beams and connections for external pre-stressing , Economically replacing members. Additional strengthening methods include: Increasing the flexural strength of floor framing members, Enhancing the axial load capacity of columns, Connecting a new frame to an existing frame, Providing steel side plate connections.

Saeed Azizia et al {9}: A two story steel building in Mashhad Iran which is located in earthquake prone area was taken as a case study by author SAEED AZIZIA for seismic strengthening. The building includes two stories & structure is made up of steel & roof is made up of joists & blocks. The gravitational load bearing system of the building includes beams with continuous-simply-supported connections in the longitudinal direction of the building and simply-supported connections in its transversal direction. The structure was modelled and analyzed using ETABS software, and the seismic upgrade is evaluated based on the Iranian codes. Iranian code proposed static and dynamic analysis methods employed linearly and nonlinearly for analyzing this structure. Iranian code no. 360 proposed approaches for structural lateral strengthening and hardening are as follows: (a) designing and implementing braces in some of the openings in both longitudinal and transversal directions, (b) constructing shear wall in building as the lateral load bearing system, (c) reinforcing masonry walls by concreting them and using their capacity as the masonry frame-filled. The structure suffered from a lack of an integrated lateral load bearing system before strengthening. Different options for strengthening was studied, and then addition of steel braces is done due to some construction limitations and cost effectiveness. Seismic evaluation was done under Iranian code to check capacity of each member & the result is after adding bracing the structure was safe against seismic loading.

Aditya P Mehendale et al {10}: The PEB concept has been gaining momentum and the scope of growth was increasing due to India huge infrastructural requirements. The scope of using PEB ranges from showrooms, complex, industrial building etc. The steel structure was not cheap so can not be reconstructed so regular maintenance was required to increase durability of structure. The durability of structure was depend upon some factors like grade of steel, joints of components, maintenance, accurate size of components. Some suggestion for increasing durability by author ADITYA P. MEHENDALE was onwards: 1) By using greater grade of bolt like 8.8,9.8 or 12.9. 2) Maintenace should be done at regular interval. 3) To get better finish & also to avoid environment effect multi coat paint system should be adopted. If all above point taken into account then it will increase durability. Maintenance period of PEB depends upon environmental zone & pollution level in which the structure is located. If the structure lies within 5km of the sea then after every 3 months maintenance is done. For high & medium polluted area the maintenance is required after every 4 months.

A maintenance procedure varies from building to building and depends upon building design, material specification and access provision. The water leakage problem from roof is due to gap between lapping. So to overcome from this problem they provide adhesive sheet between the gaps, drilling done properly. To overcome from corrosion problem thick coat painting is provided.

III. Finding

1] Pre-engineered building has higher resistance against seismic load. The unexpected loss of stiffness may also lead to torsional effects, redistribution of internal forces & thereafter to failures

2] The strength of beam specimen influenced by preload ratio, length of cover plate. An increase in the ultimate load capacity as increase in the welded cover plate length. As the preload ratio increases then deflection decreases

3] As the finite element analysis is done for steel connection then it shows deformed shape of connection & should give more accurate location of the affected zone. Stresses in flanges decreased & stresses in web of column increased for same acting force

4] The strengthening of the structure is achieved by adding material to increase the load carrying capacity, stiffening the member or adding additional restraint to the original section it will increase the overall resistance which reduce buckling

5] Both local & global strengthening schemes improves the strength & stiffness of CFS beams. Global strengthening scheme strengthen the beams more than local strengthening scheme in terms of strength, stiffness, ductility. Therefore global strengthening is preferred over local to increase the strength.

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