PROGRESSIVE COLLAPSE RESISTING MECHANISMS OF REINFORCED WITH FRP REBARS

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ABSTRACT: The significant aim of this analysis is to enhance a non-ferrous hybrid reinforcement model for deck bridges using Fiber-Reinforced Polymer (FRP) rebar as well as discontinuous, random distribution of polypropylene fiber. The model will have capability to solve the issues associated with rebar corrosion during the required strength, stiffness, and ductility is a drawback of FRP reinforcement systems in reinforced concrete structures. These buildings are subject to progressive collapse because inadequate continuous reinforcement. Integral part of structural design opposed the progressive collapse. However, few principles will give detailed requirements to mitigate the potential for progressive collapse. Predicting the structure behavior of building components are difficult in dynamic nature of phenomenon and finite observational tests are performed to understand the behavior of progressive collapse. Behavior of FRP beams under membrane pressure and tension. Test outputs show that addition of fibers improves the bending behavior and increases the ductility index of 40% is considered with plain concretes beam. The cracks width of Fiber-Reinforced Polymer is smaller than concrete system as well as value detected by present equation. Also, strain in FRP/FRC beams exceeds strain of concrete in compressive failure.

Keywords: Progressive collapse, Reinforced Concrete (RC), Compressive arch action, Catenary action, Finite element analysis.

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I. INTRODUCTION

In recent years, examination will conduct to solve the corrosions issue of RC. Therefore, techniques like galvanizing, using epoxy coating, cathodic protection, and stainless steel bars will be attempt. None of these treatments have proven to be completely effective. Ductility is a structural model need in designing code. In RC steel designs, ductility is usually expressed as ratio of the post-yield strain derived from the steel. The standard concept of ductility is not applicable to structures reinforced with FRP reinforcement because of linear relationship in FRP bars between strain and stress. Many techniques have been proposed to calculate the ductility index of FRP reinforced structures, such as energy-based and deformation-based methods [18].

Progressive collapse of a design is not proportionate in failure mode at which is a localized failure initially induced by anomalous loads ultimately leads to failure of much larger parts and even the failure of the entire structure. Over the past decades, terrorist attacks and extreme loads have caused many progressive collapse phenomena, resulting in important loss of life and properties. Recently partial collapse of a Reinforced Concrete (RC) building in Miami architects of the significance of structure integrity, particularly resilience. Numerous building codes and design guidelines have been issued to prevent such collapse phenomena. The Alternate Load Path (ALP) method is an effectual method to study the progressive collapse behavior of structure.

Because of the linear elastic nature of Fiber-Reinforced Polymer bending nature does not exhibit ductility as expressed in rebar reinforced designs. The improvement and expression of ductility of FRP rebars made deal of effort. This method will utilize hybrid FRP rebar. In other words, pseudoductile material is created by integrating more than two FRP reinforcement substances simulates the nature of elastoplastic. [17].

Progressive collapse is a situation in which localized collapse is followed by collapsing of adjacent elements, which in turn causes a global collapse, ultimately leading to significant loss of life and injury. Structural design against progressive collapse will never be an integral portion of structure designs[13]. The primary technique is to enhance structure resistance to progressive collapse to enhance structural redundancy for continuing the ductility of structural members [12].

Because of prohibitive costs and safety concerns, very limited number of progressive collapse experiments of 3D frame designs are performed. Alternatively, numeric simulation analysis using the Finite Element method (FE) has emerged as an effective method to study structural response and failure modes. Extensive numerical studies were performed using high-precision FE software to study the structural response of single-layer subassemblies, multi-layer planar frames and 3D designs. Therefore, the analysis develops and presented a nonlinear numerical simulation for investigating. Static outputs and dynamic history curve confirms the compliance stiffness greatly improves the collapse resistance of Steel-Fiber reinforced Composite Bar (SFCB) frame. A conservative Dynamic Incremental Factor (DIF) has been proposed for SFCB frame to control the progressive design collapse. Additionally, the influence of some significant structure parameters is also possible that is Longitudinal beam supports extraction of the structured capacity of SFCB frames are also investigated by specific analysis.

Redundancy also permits the shape to reallocate the weight from a portion of shape that misplaced structure integration as opportunity stiffer load route. This is most effective for completed through continuation of shape and supply of good enough ductility. The mitigation of modern collapse, attempt is directed at each code provisions and work. In standard codes provision, structure reinforcement is needed to enhance redundancy and ductility in structures. To acquire continuity in structure elements, bind force is needed to bind factors collectively in order that they perform as single unit.

Damage or removal of complex structural components deforms the connecting panel until the adjacent beam or plate loses its ability to rotate. Second, the chain effect allows the beams to pass vertical load with high displacements. The chain effect considering the last line of defense in structures to mitigate progressive collapse if structural members are removed or damaged. The excellent properties of FRP suggest these materials will be potential solution for corrosion-resistant concrete reinforcement. The characteristics includes high corrosion, good strength-to-weight ratio, and fatigue resistance.

Failure of structure elements under extreme stress, such as natural disasters, explosions, vehicle impacts, and fires, will result in localized damage being disproportionate to extent of eventual collapse, which is known as progressive collapse or used to define the word disproportionate collapse. A growing number of collapses, including the Ronan Point Apartments, the New World Hotel, the AP Mulla Federal Building, and the 9/11 attacks, have received a lot of attention. Especially since attacks, the civil community will begin to comprehensively and thoroughly examine the problems of progressive collapse for structural stability of building designs. Progressive collapse is associated with Low Probability and High Consequences (LPHC) and as a result, understanding of progressive collapse resistance mechanisms relies heavily on experimental studies given the strength for data from real-world experiments.

Most of the FRP applications in civil can be categorized into 2. The initial is to replace steel rebar or prestressed strands with Carbon Fiber Reinforced Polymer (CFRP), Glass Fiber Reinforced Polymer (GRP)/ aramid fiber reinforced polymer. The next use is to reinforce beam which are designed with FRP frames or panels. Large-scale applications for these material delay because of high cost FRP reinforcement compared with steel, the lack of structure regulations, and brittle behavior of FRP that reduces ductility. Therefore, the value of FRP, especially carbon fiber, is dropping and some standardization efforts are in progress.

II. LITERATURE SURVEY

Mohammad R. Ehsani, Hamid Saadatmanesh, et.al [19] has investigated the need of utilizing GFRP as initial concrete reinforcement. They concluded the beam cracks would have been caused by reduced tension in rebar as well as concomitant cracks in concrete.

Adam, J. M., Parisi, F., Sagaseta, J., & Lu, X et. al. [3] classification methods are described in experiments which are divided into column-beam connection, subassemblies (with or without slabs), planar, spatial frames, real building, and flats slab subassemblies. A subassembly refers to an instance that simulates the local members within the area directly affects removal of the column. A typical example is axially clamped two-span beam, which is used in many experiments to study Compressive Arching Action (CAA) and Coarse Aggregate (CA). A planar frame is a system of beams and columns with two or more floors, allows simulating the Vendeel effect. A space frame is a three-dimension beam, column, and plate system with more than two floor, and spaceframe observations typically study plate membrane behavior..

Azim, I., Yang, J., Bhatta, S., Wang, F., & Liu, Q.-F.et.al [2] In RC frame structures exposed to progressive collapse from last years, it has been confirms the resistance mechanisms such as beam action, CAA, CA and Vendeel action will provide resistance to progressive collapse. Jet and Bendale actions primarily provide resistance when the structure operates through small stages of deformation while the plastic hinges are still in effect. CAA only exists if the surrounding elements will provide enough lateral restraint to apply thrust. Mostly, the loss of corners, sides, penultimate, and antepenult sides column causes malfunction or lack of CAA, so the risk of progressive collapse is high in these scenarios. CA is noticeable when the plastic hinges at the beam-to-column connection fail, putting tension on the longitudinal rebar of the beam. Observations suggest that CA will be activating the vertical displacement of the central pillar stump that exceeds the depth of adjacent beam.

Ren, P., Li, Y., Lu, X., Guan, H., & Zhou, Y., et.al [8] suggested that plates could alter the load pattern distribution of the actual column-beams structure. As plate impairs deformations suitability of the structure, beam damage occurs due to over-stiffening and replacing beam CA with plate.

Qian, K., Lan, D.-Q., Fu, F., & Li, B, et.al [1] described the effect of the filling wall. Partial-height panels have little impact on load-bearing capacity of reinforcement concerted designs, during the full-height panels perform as similar supports and increase load-bearing ability of the structure.

Baghi, H., Oliveira, A., Valenca, J., Cavaco, E., Neves, L., & Julio, E. et.al [4] implemented macro-finite method utilizing eccentric truss components. Generally, ignore the effects of panel walls can lead to significant errors in predicting structural stiffness, strength, and failure modes.

Qian, K., & Li, B., et.al [11] investigated the variation between interior and exterior distance scenarios and conducted examinations on beam-column connections. The results showed various failure modes of two sampling sites.

Lim, N. S., Tan, K. H., & Lee, C. K., et.al [6] The removal scenarios of corner and outer columns were studied, and experiments showed that reinforced concrete slabs were suspected of failure in bending when corner columns were removed, and punching failures when outer columns were removed.

Dat, P. X., & Tan, K. H.et.al [10] described the collapse resistance of subassemblies under the penultimate outer column as well as inner column removal outlines, and outputs showed that there was a discrepancy in CA in the different scenarios.

Qian, K., Weng, Y.-H., & Li, B.et.al [5] studied the effect of multi-column spacing on RC and flat plate structure. The outputs show the removal of multiple columns could not effectively motivate the load resistance mechanism. Therefore, the compressive membrane effect for falling plate effect prevents punch failure and subsequent progressive collapse of flat plate structure.

Yu, J., & Tan, K. H., et.al [7] introduced details seismic which are typically for the structure to increase the space of stirrups at the beam ends, providing stirrups at beam-to-column junctions, and bending the stirrups at 135 degrees instead of 90 degrees. In some cases, additional reinforce is also developed longitudinally. All relevant observations are performed with the center column, except for the removal of the corner columns.

Harris, H.G., Somboonsong, W., and Ko, F. K, et.al [16] examined reinforced with hybrid FRP and found that ductility of these rebars may be near to the steel reinforced beam. Although the technique achieved some better results in investigation, its practical application is limited due to the complex and expensive method for hybrid rebar. Another method is to enhance properties.

Alsayed, S.H., and Alhozaimy, A.M., et.al [15] describing adding 1% steel fiber can increase the ductility index by up to 100%.

Li, V.C., and Wang, S., et.al [14] described the FRP rebars reinforced with engineered cementitious composites exhibited much better bending behavior greatly improved ductility.

Qian, K.; Li, B., et.al [9] performed a series of progressive collapse tests on beam-slab subassemblies with corner and central supports to study the slab effect. According to their test results, considering plate contributions can significantly reduce the likelihood of progressive collapse. Finite Element Method (FEM) is widely used today due to its advantages such as cost savings, time savings, and ability to numerically test full-scale samples. FEM simulation excels in the area of progressive collapse because it can draw the entire building model. Finite Element method used in commercial programs are more accurately and reliably simulate the investigate of RC structures under impact and are useful for studying various design variables..

III. EXPERIMENTAL PROGRAM

Two half-scale samples were investigated the progressive collapse resistance mechanism and its capability of RC beam-columns subassemblies based on an alternative load path approach. Figure 1 show effects of column for transferring the typical building. Doubling the span significantly increases the bending moment (approximately four times). Additionally, if the beam is designed to have a negative moment, the moment on the missing support will reverse direction and become positive. All these changes may not have been reflected in the traditional design. A total of 12 bars, i.e. 6 test groups, were examined. Every test group consisted rebars similar to monotonic loads and one to more cyclic load/unload.

Materials: FRP rods – In this analysis, three commonly used FRP rods, namely Glass Fiber Reinforced Polymer (GFRP) #8 (25 mm), #4 (13 mm), and Carbon FRP #4 (13 mm) was used. (CFRP), is shown in Fig 1. The surface of the FRP bar is tightly wrapped with spiral fiber strands, depressions are made with rebars as well as sand components are attached to the plane to increase the bond strength. GRP No.4 has a filament pitch of about 25.4 mm and is spirally rolled at an angle of about 60 degrees to longitudinal direction. GRP No.8 has a filament pitch of 22 mm and is spirally wound at an angle.

A cylinder was sampled and examined to calculate Young's modulus. In practical application, volume fraction (Vf) of 0.5% polypropylene fiber is utilized to fabricate the FRP to take advantage of the fiber while ensuring better capability of the concrete. The effect for various volume fractions are not a variable examined. The compressive strength was tested.

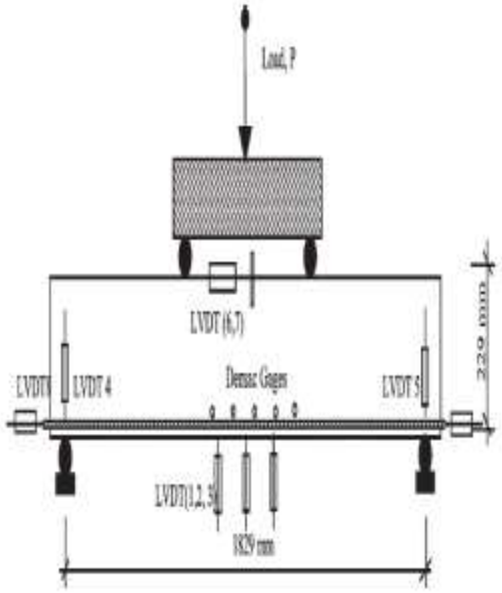

Fig.1: Flexural Beam Setup

A four-point bending test was performed as shown in Fig. 2. Three of Linear variable differential transformers (LVDTs) were mounted in the test area (deflection-only area) of the beam that detects mid-span deflections as well as measure warpage. The FRP rebar was fitted with gauge to calculate the deflection of the rebar. Two LVDTs are mounted on upper portion of beams to note the compressive stress of the concrete. A test area, a Demac gauge was fixed 38 mm above the bottom of the beam surface (at the same height as the longitudinal rebar) to measure the crack width. The crack width at the reinforcement was also measured using a microscope. In addition, it attached to two LVDTs to ends of beams to note the relative displacement.

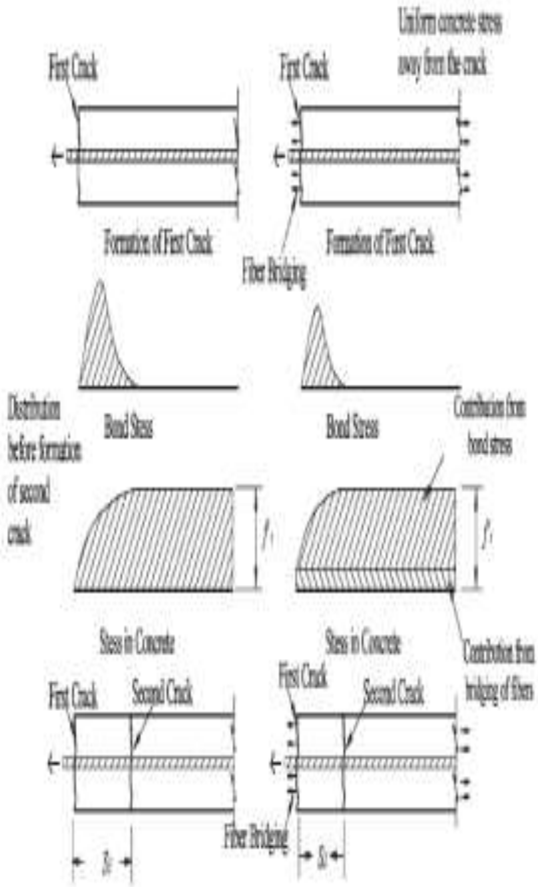

Fig.2: Crack Formation

Loads were applied in stages with hydraulic jacks and measured with load cells. It took 3 steps before it started cracking and 10 steps before it broke. The beam was monotonically loaded until it broke. The remaining beams were subjected to continues loading/unloading cycle of 40% as well as 80% of its volume to evaluate residual deflection, crack width, and energy absorption ability.

The average crack distance is 40% to 80% of the bending strength. As the load increased, the crack space is decreased slightly. When comparing the crack space of plain concrete and FRC beams, the crack spacing at 80% of the ultimate load is virtually the same for both plain concrete and FRC beams, whereas the crack spacing for FRC beams is substantially the same. Crack spacing was found to be different. A beam was about 20%. Less than a simple concrete beam at working load (40% of end load). The addition of fibers slightly changes the cracking mechanism. Fiber bridging allows some tensile loads to be transmitted across the crack. Concrete tension is caused not only by bond tension, but also by fiber bridging. Due to the fiber contribution, less cohesive stress is required to achieve the same breaking stress.

As the moment increased, crack occurs in test section if the breaking moment was crossed. As a result, the bending stiffness of the beam was greatly reduced and the curve was much softer. Due to the linear elastic behavior of the FRP reinforcing bars, the FRP reinforcing beams did not yield as expected. The curve increased almost linearly until the concrete fractured. The mid-spans measurement strain of rebar as well as concrete moments which are implemented. It is observed after crack formation, the strain for increases mostly to linear until the loss.

The difference in moment-strains curve between plain concrete beam and FRP is striking. For simple concrete beams, the concrete collapses and breaks as soon as it reaches its limit, resulting in sudden relief of the stress in the rebar. However, for FRC beams, the concrete is held when the beam reaches its limit, the stresses in the concrete and rebar continue to increases gradually. Furthermore, adding fibers for the ultimate stress of the concrete.

IV. RESULT ANALYSIS

The performance analysis of progressive collapse resisting mechanisms of reinforced with FRP rebars is observed in this section. FRP rebars are compared with plain concrete beams with parameters interms of average crack spacing, crack width and flexural behaviour.

Table.1: Performance Analysis

Parameters	FRP Rebars	Plain Concrete Beams
Average Crack Spacing (mm)	122	152
Crack Width (mm)	0.36	0.64
Flexural Behaviour (kN.m)	42	51

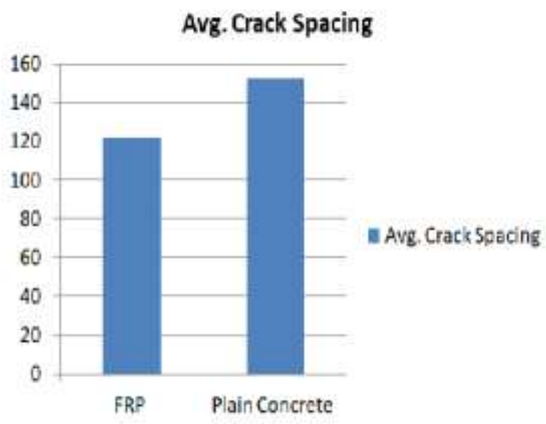

Fig.3: Average Crack Spacing Comparison Graph

In Fig.3 average crack spacing with FRP rebars and plain concrete beams. The FRP rebars shows low crack spacing.

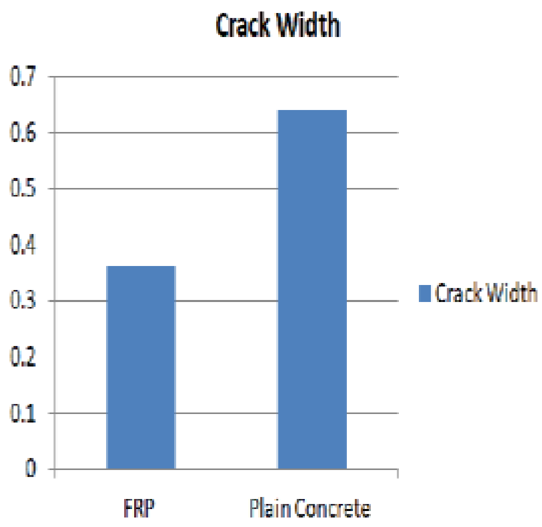

Fig.4: Crack Width Comparision Graph

Crack width comparision graph is observed in Fig.4 with FRB rebars and plain concrete beams. FRB rebars shows low crack width.

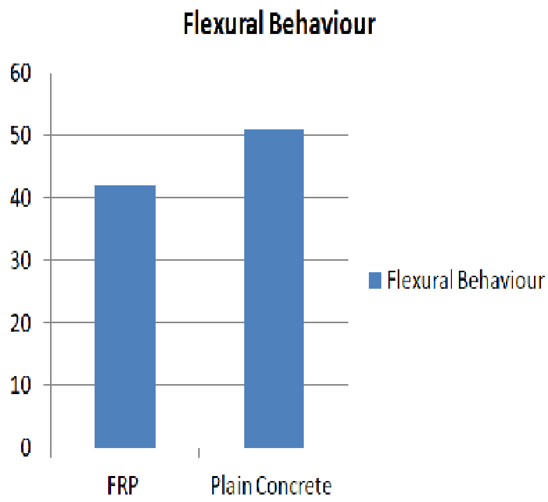

Fig.5: Flexural Behaviour Comparision Graph

In Fig.5 Flexural behaviour with FRP rebars and plain concrete beams. The FRP rebars shows low Flexural behaviour.

V. CONCLUSION

Feasibility of Non-Steel Hybrid Reinforcing System that combines FRP Reinforcing Material and Polypropylene FRC. The deflections predicted by the current agree fairly with experimental outputs, particularly at working loads, and are recommended for framework purposes for simple concrete and FRP rebars. Provides reasonable cracks dimensions predictions for both beams. Forecasts for American Concrete Institute (ACI) 440 are conservative.

Concrete failure strains measured on Fibre-Reinforced Beams (FRB) are higher than those on simple concrete beam. Their range was from 4,000 microstrain to 5,500 microstrain, and the FRB beam of 4,500 microstrain. On the other hand, for ordinary concrete beams, microstrains were measured with range of 2,950. With the addition of fibres, bending behavior shows an increase. The simple concrete beams, FRB beams have relatively high ductility at failure. Moreover, both simple concrete and FRB beams provided a sufficient level of deformability as described in this approach.

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