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Laboratory investigation on the buckling restrained braces with an optimal percentage of microstructure, polypropylene and hybrid fibers under cyclic loads

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ABSTRACT

Normal braces have a high stiffness but are buckling under compressive strength and have very low ductility. To overcome these disadvantages in recent years, a buckling restrained braces system has been used. In this study the optimal percentage of Microstructure, Polypropylene and Hybrid Fibers were determined by using tensile and compressive test, the results exhibited that the highest rate of tensile and compressive strength were occurred in the case of reinforced concrete with polypropylene fibers and the composition of polypropylene and metal fibers as known hybrid fibers compared to the non-fibrous concrete for test specimens containing (0.15–0.3) percent polypropylene fiber and reinforced concrete with the composition of polypropylene and sinusoidal fibers related to test specimens containing (1.5%) metal fibers. Also, the results of scanning electron microscope imaging of concrete core sheaths obtained from fiber concrete in this study showed that fibers play a micro role in concrete. In addition, this research the effect of using optimum amount of fibers in the concrete sheaths in the buckling restrained braces were investigated. For this purpose, 6 samples of buckling restrained braces were made and examined in three modes. Concrete sheaths of buckling restrained braces without fibers, with polypropylene fibers and composition of polypropylene and sinusoidal metal fibers were the three modes. The samples made were then shifted to the intended location and installed in the laboratory under the loading protocol of BD/SAC – 02/97, also by applying the horizontal displacement contained in this protocol, the applied load and the amount of related peripheral displacement were calculated. Backbone, loading cycle-force, horizontal displacement – lateral displacement, push over curve and bilinear behavior model were finally drawn. By examining the results, it is shown that the maximum number of loading cycles, the coefficient of ductility, the energy absorption, and the maximum amount of applied force in the specimen produced by the composition of polypropylene and sinusoidal metal fibers are accrued.

1. Introduction

Normal braces have a high stiffness but are buckling under compressive strength and have very low ductility, also due to design of a thin compressive member and bending brace members, the cross-sectional area is increased. In recent years to overcome these drawbacks, a new bracing system namely buckling-restrained brace (BRB) has been investigated. Buckling-restrained braced frame (BRBF) is considered as a special category of concentric braced frames (CBF). These braces are more ductile and absorb more energy as compared to normal braces, because these brace members show the better resistance to the tensile and compressive forces. These members also reduce the overall buckling and deformations produced by external forces exerted to the structure and prevent the relative displacement of the design in the floors. In buckling-restrained braced frames (BRBF), the energy absorption occurs during tensile-compression stable delivery cycles [1].

The main part of buckling-restrained brace is a metal core that usually is fabricated by using steel material, which prevents it from buckling under the external imposed pressures. Therefore, several methods have been proposed to prevent core buckling in the pressure. The most common method for the prevention of core buckling under pressure is placing the core in a steel sheath and filling it compactly with a cement mortar such as concrete [2]. The buckling-restrained braces are made in such a way that the core can act along the longitudinal direction independent of the buckling mechanism. In other words, all of the axial force that is exerted to the braces is tolerated by the core. By preventing the buckling of the core, this element can act such as tensile strength produced in the structure, and thus increases

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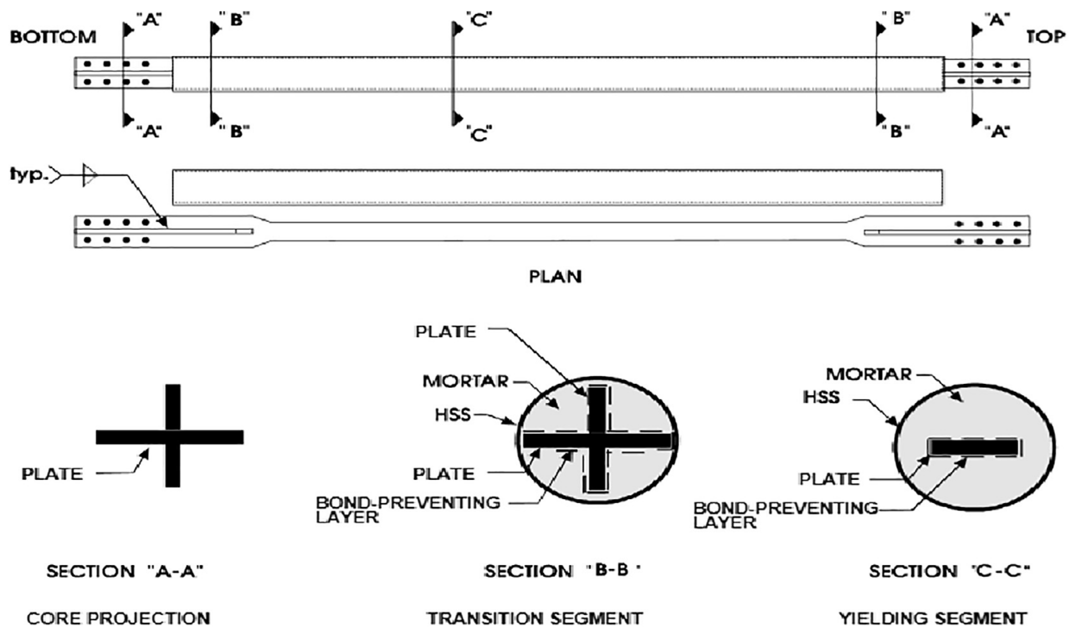

Fig. 1. Distinct sections of a buckling-restrained brace (BRB) [6]

the ability of absorbing energy dramatically [3]. The idea of buckling-restrained braces was first introduced in Japan in 1973 by Wakabayashi et al. [4]. These braces were widely used in Japan after the Kobe earthquake (1995). In Japan, buckling-restrained braces are mostly used as hysterical dampers in steel moment frames, and for their design the philosophy of designing damage resistant structures proposed by Wada is being adopted. In this idea, the design is done to ensure that during the earthquake, the main structure remains elastic, and only the dampers will absorb the earthquake energy. Therefore, after a major earthquake, it is expected that the structure will return to its original state by replacing the braces [5]. In the United States, for the first time in 2000, buckling-restrained braces were utilized. After recognizing the value of non-buckling braces by engineers in the United States, a group of researchers at the California Structural Engineers Association, in collaboration with the American Steel Institute in 1999, published the proposed rules for these types of frames. These braces consist of four distinct parts in terms of behavior and function, as shown in Fig. 1 [6].

So far, several experiments have been carried out on different types of buckling-restrained braces. The results of these experiments show that the non-elastic hardness of these non-buckling braces is relatively low and decreases in each cycle with related to the previous one. The significant point about buckling-restrained braces is that these braces have more compressive strength than their tensile resistance. The reason for this phenomenon is that during compression the axial force transfer from the core and prevent from buckling of the structure [7].

In order to investigate the effect of the use of fibers in the core sheath concrete of buckling-restrained brace, we started with an introduction of the researches carried out in this field. Although, concrete is a substance with a very high compressive strength and widely used in the construction industry, but due to its very low tensile strength and in the case of cracks in areas exposed to moisture and corrosion it exhibits a weak behavior. The tensile strength of concrete can be increased by adding the reinforcement but this process automatically enhances the corrosion of the reinforcement itself. To solve this problem, the idea of using fiber concrete technology was introduced. One of the methods used is the use of polypropylene fibers in concrete. The idea of using these fibers dates back to the 1950 s, and the material, shape, percentage and fiber ratio, as well as the way of producing fiber concrete in this field have been improved. The researches carried out indicate the synergistic effect of hybrid fibers (polypropylene fibers - metal fibers) and its effect in crack reduction process on macro and micro scales [8]. The use of a volumetric volume of 0.5% of steel fibers in a mixture of lightweight aggregates results in changes in the mechanical and thermal properties of concrete:

1- Increase in compressive strength and Young's modulus, 2- Increase in tensile and strain strength after cracking and thus increasing the energy absorption and bearing capacity, 3- Lightweight reinforced concrete mixes with steel fibers show better thermal insulation performances [9]. The results indicated the use of polypropylene fibers with a different aspect ratio and geometry of amount (0.25, 0.365, 0.5%), the volumetric percentage of concrete, improve the mechanical properties of lightweight concrete, including increase of (tensile strength, compressive strength and bending resistance) in concrete reinforced with 0.5% polypropylene fiber [10]. The effects of adding steel and polypropylene fibers to high strength concrete (HSC) using steel fibers (hooks with length of 60 mm in 4 volumes of fibers in the range of 0.25%, 0.5%, 0.75%, 1%) and Polypropylene fibers (with a length of 12 mm in the range of 0.15%, 0.3%, 0.45%) and having 10% micro silica instead of cement showed that the hybrid fibers (steel-polypropylene) improved the mechanical and sustainable properties of high strength concrete (HSC). Among the various combinations of steel and polypropylene fibers, the best performance was obtained from the mixture obtained from 0.85% steel and 0.15% polypropylene fibers. The fiber used in concrete reduces the absorption of water and, depending on the fiber type, slightly or significantly decreases the electrical resistance of it as compared to non-fibrous concrete [11]. Efficiency after cracking of various types of recycled polypropylene fibers obtained from industrial waste showed a good level of tensile strength, the Young modulus, of reinforced concrete with recycled polypropylene fibers, and these properties allow the use of recycled fibers in reinforcing the concrete of a column [12].Laboratory studies of seismic performance of reinforced concrete columns showed that effect of steel fibers is greater than the effects of hybrid fibers (polypropylene-metal fibers). In these concrete columns, the buckling performance of longitudinal reinforcements, ductility and energy dissipation seems more favorable [13]. As the polypropylene fibers start melting generates a steam which improves the performance of the polypropylene fiber concrete against fire [14]. Laboratory studies indicated that the use of polypropylene fibers reduced the, density, modulus of elasticity, and compressive strength to a small extent, on the other hand, increased the shrinkage or (volume drop) of the concrete due to its initial drying process, controls the cracking, and also reduced the permeability and