Enhance Rockfill Dams Face Concrete by Using Different Fibers

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Abstract:- The forces result from water pressure are interfere with each other which produce a difficulty to recognize and measure their effects. for that, enhancing reinforced concrete dam face is an essential structural task which is used to improve dams surface form different stresses reflection and deformation. the effect of SFRC and PFRC protect and improve reinforced dam concrete face strength. In this study, the experimental work using a model of SFRC, PFRC panels was carried out to study response and resistance against subjected loads. The experimental program marked as four groups in which each group contains a panel without steel fiber a panels with SFRC, a panel with PFRC and finally a panel with mix SFRC with PFRC. The specimens of slab concrete with the dimensions of 500 × 500 × 60 mm have been subjected to different testing machines to obtain the shear strength behavior of each specimen type. The recent research results indicate that the steel fiber has a significant improvement on the behavior of concrete in groups under the same conditions, also in general the shear strength improved with respect to PFRC and the results observed more concrete ability with it. Finally, mixing SFRC with PFRC presents a superior results of concrete mechanical characteristic which can be used as an enhanced alternative of dam concrete surface.

Keywords: SFRC, PFRC, shear strength, conventional steel reinforcement.

INTRODUCTION

Concrete faced rock-fill dams, CFRD, is the term used to describe a certain type of dam that contain a dam body of rockfills that is compacted in layers. The great number of dams which have been built already in the world today or those to be built in the shear have been subject of special emphasis on the questions of dams' safety which means the quality of averting or not causing danger, or loss[1]. When designing CFRDs there are certain properties that have to be assessed thoroughly such as zoning of the dam body, filling materials, design of the dam body, various analyses and seepage control. Dam Safety issues, as we visualize them, are not only taking care of the proper design and good construction of dams only, but extending this to more understandings of the natural hazards impacting them such as enhancing their materials and ancillaries, which merits special attention. The material quality is mainly determined by the local geology and highlights the importance of good geological surroundings in order to exploit all advantages with the dam type[2].

ROCKFILL DAM CHARACTERISTICS

Embankment dams are subjected into two main categories depending on construction materials, they are rockfill dams and earthfill dams. Rockfill dams are a structural resistance dams against failure, which is used rockfill shell, core, transition zones, and facing zones. These types of dams have a role to minimize leakage through embankment [3]. The dams type is determined by considering various factors associated with topography and geology of the dam site, quantity and quality of construction materials available. The inclined core is adopted Stead of the center core, for instance, in cases where the dam foundation has a steep inclination along the river, where a blanket zone is provided in the previous foundation to be connected with the impervious core zone, and where different construction processes are available for the placement of core and rockfill materials.

The design of dam body includes several properties of the CFRD. Ensuring good material for the CFRD body is essential to keep it competitive, both from a technical and an economic stand point. The rule is that only a small part of the dam filling materials should be excavated from quarries to make it cost effective. This is enabled by dividing the CFRD body into zones that have different properties[4]. The zones can have different relative volumes depending on how large the dam should be, surrounding geology, bank slopes etc. High structure of CFRDs measurements and observations should be produced before, during and after construction process. The observations of managing the dam implementation project during the early phase of construction should guide the construction resulting in a more optimized design in the later phase. The design properties that be used at high CFRDs considered for dams of concrete faced rock-fill type can be described in below:

i. Overtopping

The biggest risk for a CFRD is the case of overtopping. This phenomenon caused CFRDs to fail in many times in the past. When starts of water overtopping the dam, an erosion process appear which will reduce the dams general stability and could cause a fail. To counter this risk, an internal warning system could be installed to indicate too large flows in the river or too high levels in the reservoir. If this warning system indicates dangerously high levels of water (usually the CFRD is designed for the 10,000-year flood), the outflow though the spillways can be increased and the risk of overtopping is then reduced although a decrease in energy output is also likely[5][6].

ii. Frost and ice

The colder climates environment and the temperature change during effects on dam situation [7]. For CFRDs this affects the concrete face. The expansions in face concrete can cause cracking leading to leakage and erosion. The main dam body of the CFRD is fairly resistant to frost problems due to the nature of the rock-fill.

iii. Seismic

There are some cases of CFRD's being subjected to seismic forces and earthquakes. This can be potentially disastrous for the dam. It can fail or be heavily damaged due to the dynamic forces of the earthquake[8]. The face slab suffered heavy cracking as well as the parapet wall on the dam crest. The cracking of the face slab resulted in somewhat higher leakage. Also the seepage under the dam increased after the quake.

CRACKING BEHAVIOR

Cracking develops within zones of tensile stresses within earth dams due to differential settlement, filling of the reservoir, and seismic action. Since cracking cannot be prevented, the design must include provisions to minimize adverse effects. Concrete cracking is a result of the combined effects of mechanical loading and environmental conditions. Stress mechanisms that cause can cause concrete cracking can be divides into those that happen in the plastic condition and those that take place in the hardened state, then it might also be tell apart by whether they arise from internal factors or from external factors[9]. Cracks could appear form these distress in concrete slabs resulting from a number of variables such as water inclusion, seasonal temperature changes that causes expansion and contraction and the exposure to sun. Understanding the type of crack formed and its effects is significant to structural stability[10]. The structural capacity for a designed live load and a super imposed dead load conducted to determine the actual floor capacity. Loreto et al, in 2013 proposed cracks behavior based on different variables. They tested FRCM samples in tensile coupon hydraulically. Also, the first crack is occurring based on the load in every crack position and transported to the matrix using the fabric with creating multiple cracking patterns[11] with stress-strain for fully-clamped FRCM in tension[12]. The load effect is completely carried via the fabric elements to reach the tensile strength. It is clear from the figure that can compare the crack outlines on the lowest position of the tested slab. by increasing the subjected load, the steel yielding, depth, and width of the cracks dynamically increase. the interaction might make the failure crack pattern [13]

DARBANDIKHAN DAM AS A SAMPLE OF PROBLEM IN IRAQ

The Darbandikhan Dam is a multi-purpose embankment dam on the Diyala River in northern Sulaymaniyah Governorate, Iraq. It was constructed between 1956 and 1961The dam is 128 m (420 ft) tall and 445 m (1,460 ft) long (535 m (1,755 ft) if the spillway section is included). Its crest is 17 m (56 ft) wide and at an elevation of 495 m (1,624 ft). The structural volume of the dam including rock, clay and filters is 7,100,000 m3 (9,286,449 cu yd). The dam collects water from a catchment area that covers 17,850 km2 (6,892 sq mi). Its reservoir, by design, has a storage capacity of 3,000,000,000 m3 (2,432,140 acre·ft). Of that capacity, 2,500,000,000 m3 (2,026,783 acre·ft) is active (or useful) storage while 500,000,000 m3 (405,357 acre·ft) is dead storage. At a normal elevation of 485 m (1,591 ft), the reservoir covers an area of 113 km2 (44 sq mi)[15][16].

Figure 1: General view of Darbandikhan Dam [15]

after first filling of the Darbandikhan reservoir, 1961-1962, unexpected large settlement occurred in the contact zone with the concrete intake/spillway structure. Cracks, along with settlements, are the most regular feature occurs in dams under seismic loading. Although they occur in various kinds, cracking in dams subject to earthquake can be classified in two main forms; longitudinal cracking and transverse cracking. The longitudinal cracking of embankments is cracking that is oriented parallel to the crest (axis) of the dam. While the transverse cracks of embankments are cracking that is oriented perpendicular to the crest of the dam. Although, according to Swaisgood, the longitudinal cracking on the upstream slope, is the most common type in dams subject to earthquake, the transverse cracks are the most dangerous ones which pose a greater threat to the safety of the dam[16].

ENHANCING CONCRETE PROPERTIES

Concrete is one of the most important construction materials due to its functionality and stability in structure construction. Concrete slab panels represent a structural element of modern building. The wide diversity of materials that used in slabs panels varied the behavior of slabs. For that, studying the factors and characteristics that can improve concrete slab panels considered a major issue in engineering industry where it gradually becoming a new horizon in composite material in construction project. Many independent methods have been used to achieve this target such as adding different steel-fiber. These methods are called Steel fiber reinforced concrete SFRC. SFRC described as a mixed concrete with fibrous materials. When steel fibers added to concrete, it improves the structural properties such as flexural strength and tensile. The mechanical properties achieved by using SFRC depend on several factors, such as size, shape, percentage, volume and distribution of fibers. It improves the concrete brittleness and weak endurance to shear and tensile forces. Plain concrete does not easily resist the vibrations, wind, earthquakes, and other forces. Adding fibers enhance the concrete quality against the failure. The theoretical models developed the researchers apply an applicable structural solution to modify the concrete forces resistance by using SFRC [17][18]. Steel fiber reinforced concrete (SFRC) could expressed as a composite material which have fibers as the additional ingredients. The fiber reinforcement effects as rigid inclusions in the concrete matrix. The presence of fibers with the concrete can improve the resistance of conventionally reinforced structural members to deflection, cracking and other serviceability conditions due to the inherent material properties of fiber. The fiber reinforcement can be used in three forms in concrete body; the first is one-dimensional random distribution which added advantages to the fiber shear resistance and crack control. The range of normal weight SFRC proportions presents in table 1[19].

Table 1: SFRC proportions [19]

Property	Mortar	9.5mm Maximum aggregate size	19 mm Maximum aggregate size
Cement (kg/m^3)	415-710	355-590	300-535
w/c ratio	0.3-0.45	0.35-0.45	0.4-0.5
Fine/coarse aggregate(%)	100	45-60	45-55
Entrained air (%)	7-10	4-7	4-6
Fibre content (%) by volume			
smooth steel	1-2	0.9-1.8	0.8-1.6
deformed steel	0.5-1.0	0.4-0.9	0.3-0.8

Aylie et al in 2015 studied five steel-fiber slabs, having a difference in restricting reinforcement configurations. The testing approach under increasing monotonic loading was deformation controlled.

The deformed steel fibers are more efficient due to the surface area effect which increases the cement-matrix bond this results an improvement in pull out resistance. Fibers may split out or fracture, that depend on length of steel fiber and concrete strength. The steel fibers can be found in different shapes, sizes and properties which include high tensile steel fibers, stainless steel fibers and normal steel. The steel characteristics depend on types of manufacturing process. It may produce by hot or cold working methods which are affecting the steel properties. The straight fibers which are not deformed can only bond with the concrete by friction and chemical adhesion. Steel fiber lengths are in range from 10 to 65 mm with diameters ranges between 0.5 and 1 2 mm.

The first to experimental study in this field was by Talbot in 1913 which presented a footing model for punching behavior of reinforced concrete[21]. The study was interested with deflection in the footing's concrete and marking the cracking patterns. Also, the study computed the failure loads for each footing. Talbot led to the first recommendations for independent punching shear which is published in 1925 in ACI-American Code. After that, the studies developed by many researchers to enhance the slab shear. More than a few parameters like the shear reinforcement system, slab thickness and the column size were involved to reveal their effects. The results spotted that the influence of shear reinforcement amount reduced to 40% leading to non-agreeing values. khandokar in 2015 proposed an improvement of punching shear capacity of existing flat plates by using shear reinforcements. Eight half scale frame specimens were tested based on lateral cyclic loading. The specimens were subjected to incremental cyclic loading by hydraulic jacks under gravity and constant axial load. The results showed that the joints without shear reinforcement in all specimens underwent brittle failure when used cyclic loading, but their ductility increased respectively with increased concrete strength.

Although concrete presents many advantages regarding mechanical characteristics and economic aspects of the brittle characteristics, the construction of the material remains a larger handicap for the seismic and other applications where flexible behavior is essentially required. Recently, however the development of polypropylene fiber-reinforced concrete (PFRC) has provided a technical basis for improving these deficiencies. This paper presents an overview of the effect of polypropylene (PP) fibers on various properties of concrete in fresh and hardened state such as compressive strength, tensile strength, flexural strength, workability, bond strength, fracture properties, creep strain, impact and chloride penetration[22].

EXPERIMENTAL RESULTS AND DISCUSSION

the experimental work was conducted using four specimens (A, B, C and D) in which (A) is without fiber addition, (B) contain 0.75% steel fiber, (C) contain 0.75% polypropylene and (D) is a mix of 0.375 steel fiber and 0.375% polypropylene. The load-deflection curves were obtained from the two LVDT's beneath every slab in two positions located at the center and 10 cm from the center, as shown in Figure 2.

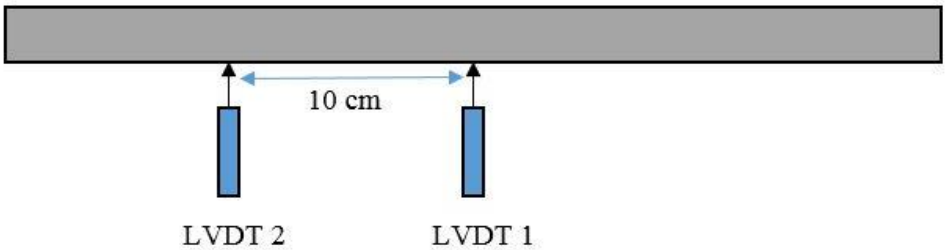

Figure 2: Location of the two LVDT's.

The results of the two LVDT's for panels A, B, C and D can be shown in Figure 4.2 . Also deflection results of each panel are presented in Table 2. Specimens deflection results indicates that the most displacement happens to the specimen without the addition of fiber, by adding the steel fiber by 0.75% leads to lower deflection values than the control, then by adding polypropylene by 0.75% the deflection remain nearly similar to the specimen without fibers for the center LVDT. And finally by adding mix of steel and polypropylene fibers, leads to lower deflection values.

Table 2: Deflection results of Group E two LVDT's.

Specimen	LVDT at the center $\delta_1^{(1)}$ (mm)	LVDT 10 cm from the center $\delta_2^{(1)}$ (mm)
A	4.1	2.9
B	3.85	2.65
C	3.79	2.55
D	3.5	2.4
(1) δ are the displacement that corresponding to ultimate loads P_u.		

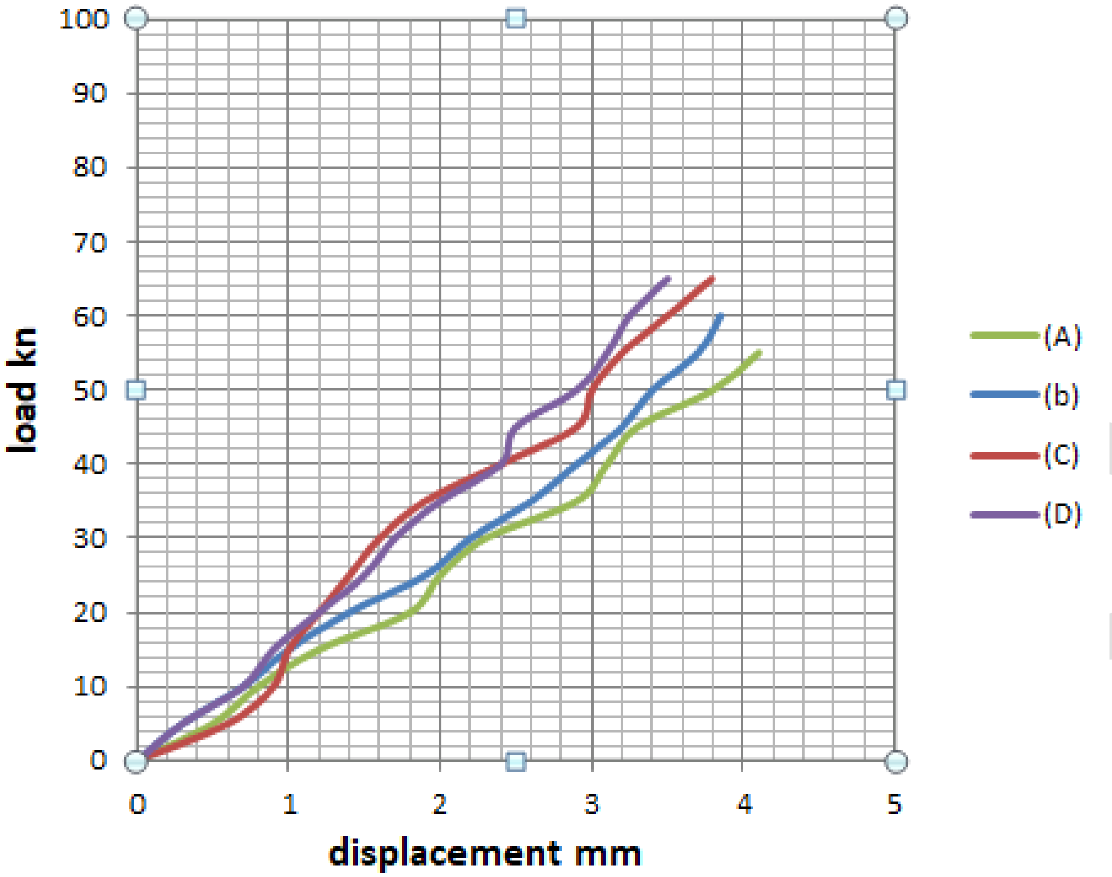

Figure 3: Load deflection of LVDT located at the center.

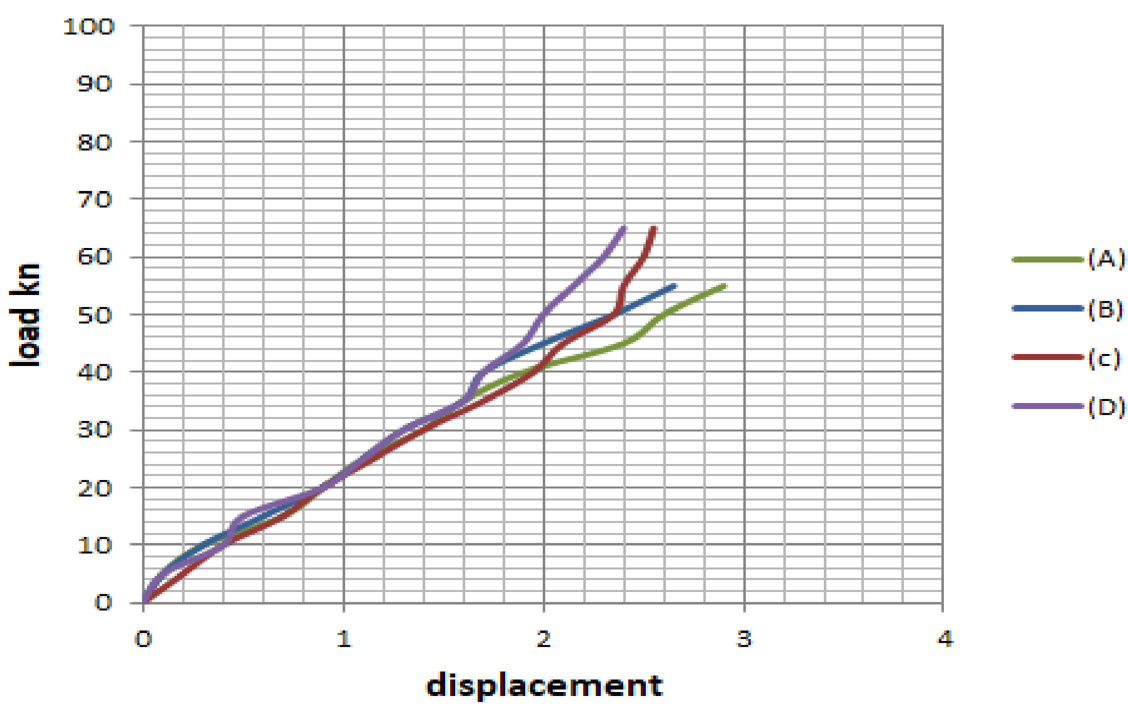

Figure 4: Load deflection of LVDT located 10 cm from the center.

Table 3 shows the results of experimental standard cylinders of the specimens A, B, C and D that was tested to calculate the compressive strength (f'_c), according to ASTM C39, splitting tensile strength (f_{sp}) according to ASTM C496, and static Young's modulus according to ASTM C469.

Table 3: Concrete mechanical properties.

Specimen	f'_c (MPa)	f_{sp} (MPa)	E_c (GPa)
A	49	5.9	36.67
B	55	6	36..82
C	58	6.21	37
D	63	6.65	37.2

COMPRESSIVE STRENGTH RESULTS

It can be noticed that the adding fibers has a significant improving effect on the (f'_c) in B, C and D. For specimen (B) the addition of steel fiber in concrete significantly improved the (f'_c) of specimens, however using 0.75 % of polypropylene slightly improve the (f'_c). On the other hand adding a mix of steel fiber and polypropylene has a significant improving effect on the (f'_c) in specimen (D) as it shown in Figure 5.

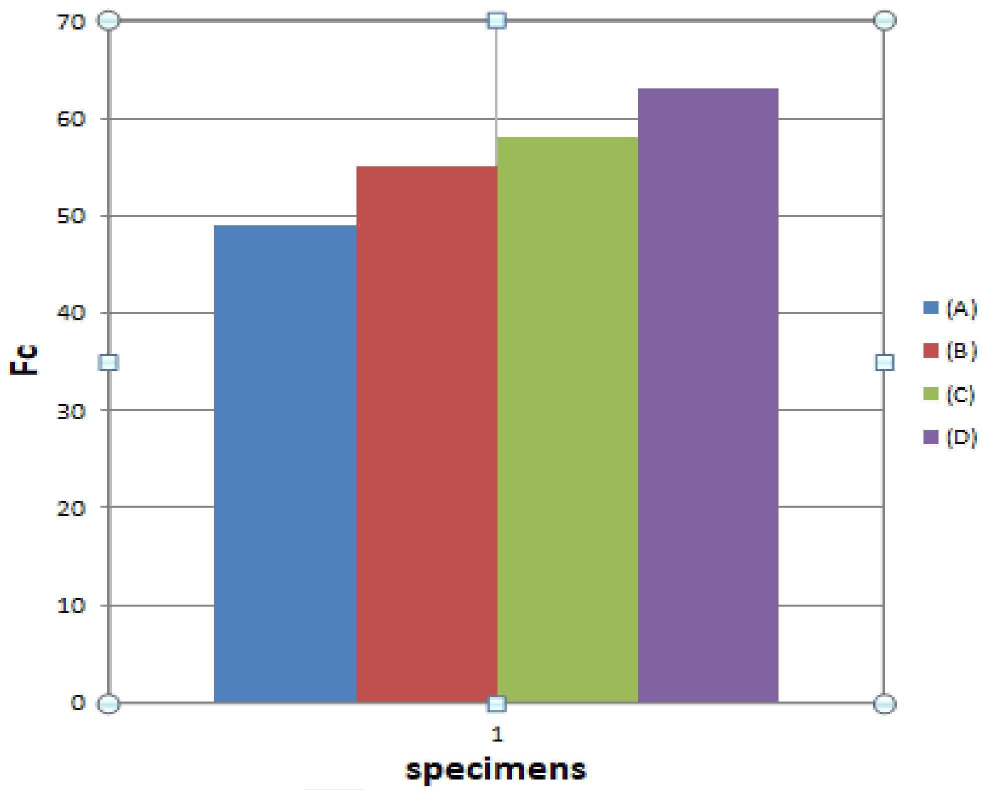

Figure 5: The effect fiber addition on the compressive strength.

The compressive strength was improved in specimens B, C and D 11%, 15.5% and 22.5% respectively.

TENSILE STRENGTH

It can be noticed that the adding fibers has a significant improving effect on the (f_{sp}) in B, C and D. For specimen (B) the addition of steel fiber in concrete significantly improved the (f'_c) of specimens, however using 0.75 % of polypropylene slightly improve the (f'_c). On the other hand adding a mix of steel fiber and polypropylene has a significant improving effect on the (f_{sp}) in specimen (D) as it shown in Figure 6.

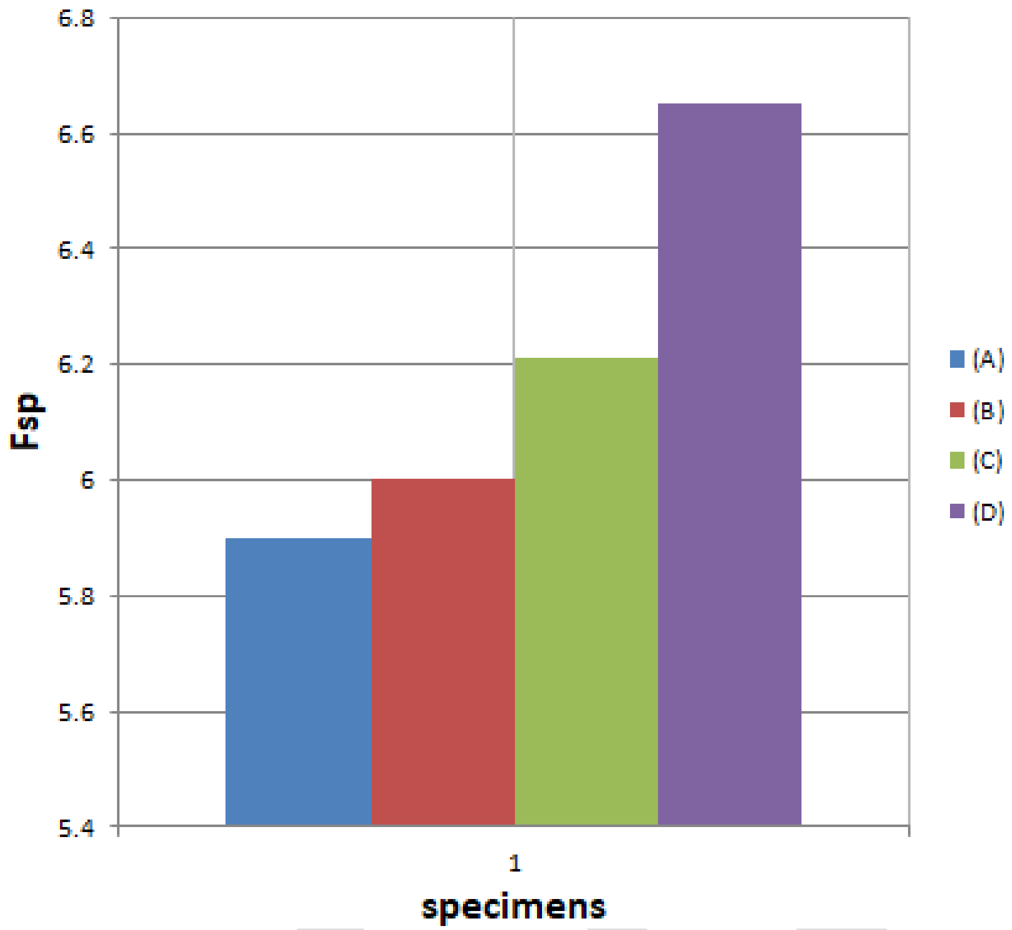

Figure 6: The effect of fiber addition on the tensile strength.

EFFECT OF FIBER ADDITION ON THE ULTIMATE SLAB STRENGTH

Table 4.3 is showing the ultimate slab strength of the concrete dam surface; it is shown for slab (A) the ultimate strength is equal to 58 Kn.

Table 5: Experimental ultimate slab strength results.

Specimen	Fiber type	Fiber V_f (%)	P_u(kN)
A	none	0	58
B	Steel fiber	0.75	65.7
C	polypropylene	0.75	68.2
D	Steel fiber	0.375	70.5
	polypropylene	0.375	

For slab (B) the addition of 0.75% steel fibers in concrete significantly improved the ultimate slab strength of specimen by nearly 11.8% comparing to the control slab (A), as shown in Figure 7.

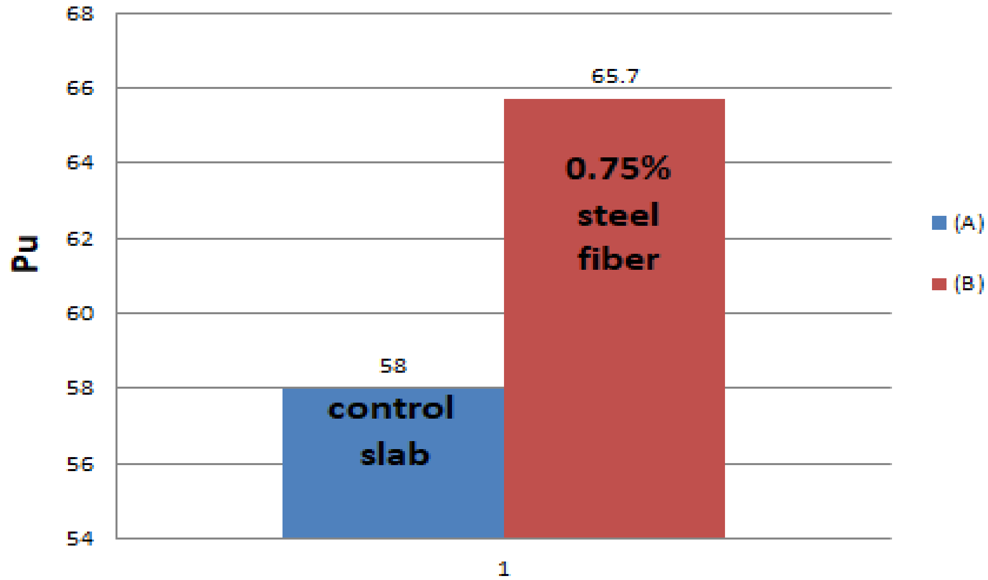

Figure 7: comparisons between slab (A) and (B).

For slab (C) the addition of 0.75% polypropylene in concrete significantly improved the ultimate slab strength of specimen by nearly 15% comparing to the control slab (A), as shown in Figure 8.

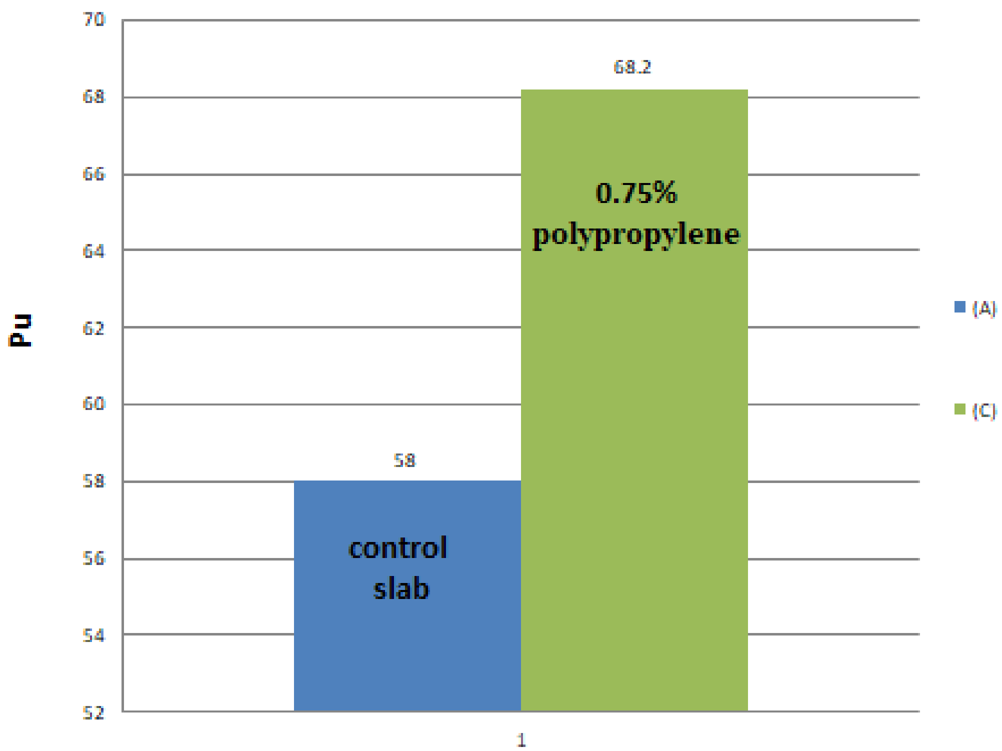

Figure 8: comparisons between slab (A) and (C).

For slab (D) the addition of 0.375% polypropylene and 0.375% steel fiber in concrete significantly improved the ultimate slab strength of specimen by nearly 17.8% comparing to the control slab (A), as shown in Figure 4.8. For all slabs, figure 9 present a comparison.

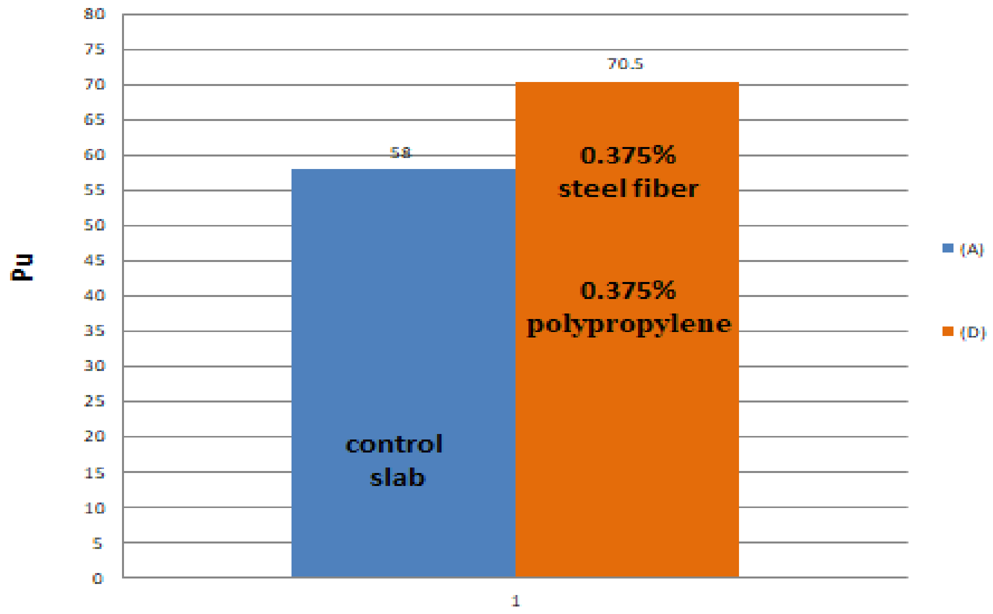

Figure 4.9: comparisons between slab (A) and (D).

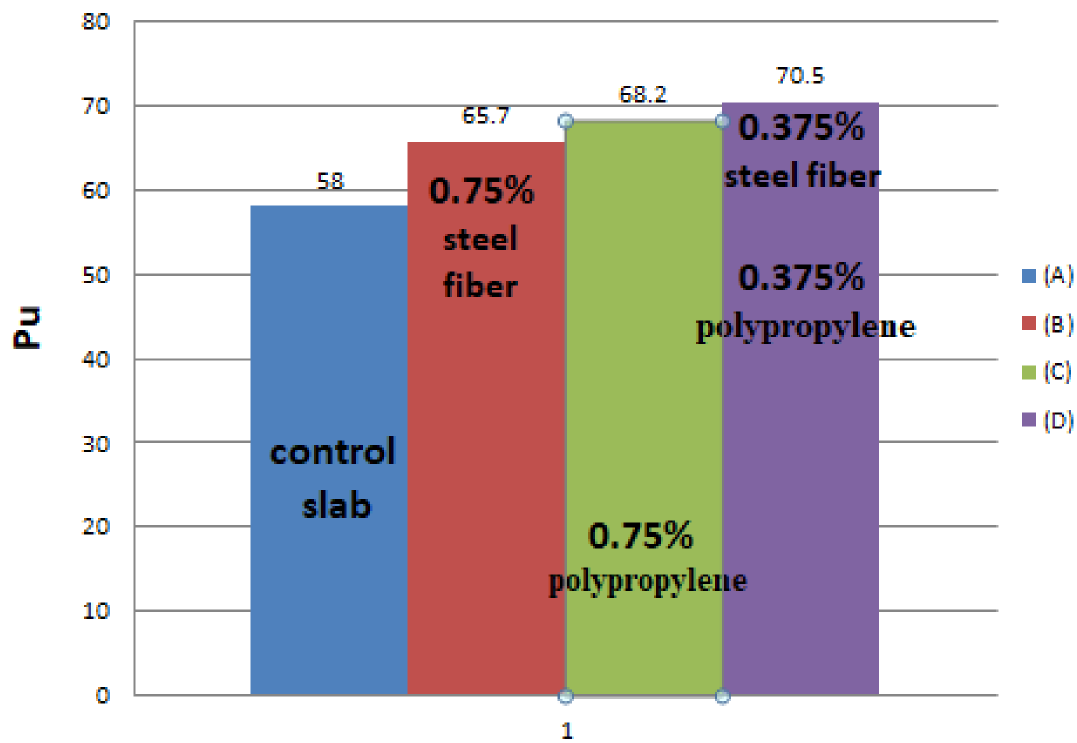

Figure 4.10: comparisons between all slabs.

CONCLUSIONS

The final results are studied and these are the conclusions:

1. Adding fibers improve deflection values, slab (D) showed the best deflection value.
2. In general, all specimens were failed because of punching shear effect with different punching shapes.
3. Adding 0.75% steel fiber, 0.75% polypropylene and a mix of 0.375% steel fiber with 0.375% polypropylene, concrete significantly improved the ultimate slab strength of specimen by 11.8%, 15% and 17.8%, respectively comparing to the control slab.
4. Adding fibers led to a great bonding without falling parts which means it enhanced the ductility behavior.
5. Adding fibers reduced the cracks and micro cracks, enabling the concrete to resist spalling.

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