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A Review of Concrete-Filled Steel Tube Elements

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Abstract

Structural elements such as composite columns and beams filled with concrete compared to reinforced concrete elements, maintenance-free concrete inside the pipe, being able to pour concrete without molds, having high rigidity and strength, increasing the strength of the concrete inside the pipe by limiting the lateral deformations and pressure elements part of it has advantages such as increasing the local buckling strength. Steel columns filled with concrete and reinforced concrete inside the USA, Japan, France, England, Azerbaijan and some other countries; widely used in high-rise buildings, bridge and pier piers, oil extraction platforms and various other engineering structures.

Beton Dolgulu Çelik Boru Elemanlarının Gözden Geçirilmesi

Anahtar Kelimeler:

Beton dolgulu çelik boru
Özel şekilli kolon
Eksenel mukavemet
Eğilme mukavemeti

Özet

Yapı elemanlarının betonarme elemanlara kıyasla dayanım-ağırlık oranının yüksek olması, boru içerisindeki betona bakım gerektirmemesi, kalıpsız beton dökülebilmesi, yüksek rijitlik ve dayanıma sahip olması, boru içerisindeki betonun yanal deformasyonlarının sınırlandırılmasıyla dayanımının yükselmesi ve basınç elemanlarının boru kısmının yerel burkulma dayanımının yükselmesi gibi üstünlükleri bulunmaktadır . İçerisi beton ve betonarme ile doldurulmuş çelik kolonlar ABD, Japonya, Fransa, İngiltere, Azerbaycan ve diğer bazı ülkelerde ; yüksek yapılarda, köprü ve iskele ayaklarında, petrol çıkartma platformlarında ve diğer çeşitli mühendislik yapılarında yaygın olarak kullanılmaktadır.

1 INTRODUCTION

Structural engineering is one of the leading sectors of both the ancient times and the times we live in. The field, which has been the subject of many studies since ancient times, has developed over time. This development is seen both in the construction market to meet the needs and in academic studies. Different building examples seen in the world and in our country are the products of this development. Steel and concrete are two indispensable building materials for structural engineering. They are used in building construction in different techniques, sometimes alone or together. One of these techniques is concrete filled steel structures (CFSS). CFSS, which is especially preferred in high buildings, has high strength. Strength / weight ratios of structural elements such as composite columns and beams filled with concrete are higher than reinforced concrete elements. Concrete inside the steel pipe does not require maintenance. Concrete can be poured without mold. It has high rigidity and strength. Lateral deformations of the concrete in the steel pipe are limited. Buckling strength increases. Steel columns filled with concrete and reinforced concrete are widely used in high-rise buildings, bridge and pier piers, oil extraction platforms and various other engineering structures in the USA, Japan, France, England, Azerbaijan and some other countries. It is necessary to know the mechanical properties of the concrete in the pipe in order to calculate the strength, buckling and local buckling control of such building elements (Eyyubov and Adıbelli, 2000).

Concrete filled steel pipes are often coded as CFST in the literature. This construction method is highly preferred in recent years. Many researches, experimental studies and theoretical studies have been done on CFST. Many of the results of these studies have positive impressions (Huang et.al., 2016; Dong et.al., 2017; Hai-Tingand Ben Young, 2018).

Figure 1. Building examples made within the method (AYDIN C., 2008)

The emergence of concrete-filled steel structures begins with the construction of very high-rise steel structures. Especially in the 1950s, methods for the calculation and design of these structures began to be developed (Kloppel et. Al., 1957). Numerous experimental and theoretical studies have been developed to make concrete and steel perform better together. New calculation methods have been introduced with each passing day (GardnerandJacobson, 1967; Knowles, and Park1969). In 1979, the British Standards Institute published a standard named "Concrete and Composite Bridges" (BSI, 1979). Thus, the principles of concrete filled steel structure design have started to be included in official standards. However, the 90s were the golden age of CFST (LukshaandNesterovich, 1991). It has become a regularly applied method. At this time, Europe, America and Japan almost competed to build skyscrapers. This construction technique has gained more rapid acceptance in these countries. With the spread of the system in the market, regulations for Eurocad 4, (1994) in Europe, AIJ, (1997) in Japan, and AISC-LRFD (1999) in America were developed. Extensive research and method development efforts on CFST continued in the 2000s. (LamandWong, 2005) If we look at the world-wide, studies have been made on parameters by forming the basis for this method. This method, which has developed very rapidly in the construction sector, is still widely used today (Krishan et al. 2016). Today, researches on the method continue to gain momentum (Moon et al., 2013).

In recent years, research on the seismic performance of CFST elements has gained momentum (Zhu et. Al., 2018; Buiand Kim, 2021; Liu et al., 2021). The history of concrete-filled steel structures does not date back to ancient times. Large-scale earthquakes in our country triggered this initiative. The increasing need for housing after the 17 August 1999 Gölcük Earthquake played a role in the development of this method.

Figure 2. Examples from around the world (AYDIN C., 2008)

2. ADVANTAGES AND DISADVANTAGES OF CFST

As with every method, there are advantages and disadvantages in this method. Considering all these pros and cons, the optimum path should be followed for construction. If we look at the advantages of concrete filled steel structures, we can explain as follows.

The steel wall surrounds the concrete core in a spiral fashion, allowing triaxial stress to form around the core. The concrete layer formed around the spiral increases the carrying capacity and ductility. In addition, when the steel tube is under extreme loads, it acts as a protector that prevents the concrete core from being destroyed and broken. Steel pipes reduce mold costs as they act like molds during manufacturing. The fact that steel tubes can be made in several layers allows the construction process to continue without waiting for the concreting process. Work time and labor costs are reduced in multi-storey buildings. Because the concrete core prevents local buckling in CFST elements, thinner-walled sections are used compared to steel elements. In the example given in Figure 3, the use of CFST is seen on a bridge pier with a high height and payload.

Figure 3. Pillar column (AYDIN C., 2008)

It is very difficult and costly to construct the basement floor with steel elements in multi-storey high-rise buildings built using only steel. For this reason, basements are generally made of reinforced concrete and are mounted on a steel construction reinforced concrete structure. This situation may cause the formation of very large column sections. This problem can be solved thanks to the high ductility feature of composite structures. Thus, it has become possible to construct high-rise structures with less cost. Famous and special structures such as the Twin Towers of the USA and Petronas Towers of Malaysia, built with this system in the world, have gained the reputation of being the symbolic structures of their countries. Almost all of the tall structures in the world are designed and built as composite. Composite floors are a good alternative as a flooring system for steel structures. Composite structural elements provide better protection of steel by resisting corrosion. Such elements are preferred in structures where high strength, total weight of the building, climatic and geographical environment are compelling factors and chemical effects are important. Safe and economical design of composite elements is not only about sizing but also about economy.

In addition to the relevant standards in the design of composite elements, complying with the recommendations of steel sheet and slip connection manufacturers will also reduce the errors and construction costs that may occur during production (Yorgun, 2005).

If we look at the disadvantages, we can list it as follows. Using two different types of materials together creates calculation difficulties due to the different behavior of these materials. Re-checks in account transactions should be strictly made. Calculating the geometrical moment of inertia in moment calculation presents difficulties. There is limited information about the force transfer and adherence at the contact surface of the steel and concrete being used. Multiple factors need to be analyzed, structurally, behaviorally and environmentally. It is also a disadvantage that the calculation and design part takes a long time. While calculating the modulus of elasticity of the composite joint, we will face some drawbacks and difficulties. In general, successful results are obtained with a good planning and engineering considering these pros and cons.

3. CASE STUDY

High-rise buildings designed with a traditional approach are mass consumers of energy and natural resources. However, during the 120 years that have passed since the first high-rise buildings, models and methods have been developed to reduce these environmental impacts, changes have been made in laws and regulations, and innovations have been made in architectural thinking as well as in materials and technology (Sev at all.2011). It is possible to see many structures related to the subject in the world and in our country. If we first look at examples from around the world, we can list the following: Canton Tower in China Guanzhong, Ganhaizi Bridge in China, Xiangjiaba Bridge and Zidong Bridge are examples to be given. As can be seen from the examples, we can observe these structures widely in China. Wushan, Zhijing River, Maocaolie, Taiping Lake Bridge are among the examples that can be given. The following examples are Petronas Tower, Sail Singapore, World Financial Center and Sky Tree for the system commonly used in high-rise buildings.

Figure 4. Ganhaizi Bridge, China (Web source-1).

Figure 5. Canton Tower, Çin (Web Source-1).

Figure 6. Petronas Tower (Web Kaynağı-2)

One of the best examples in our country of CFST type structures, which are widely preferred in high-rise buildings in the world, is the Nurol Life building. It said structure 2 is shown as Turkey's highest building is built with construction techniques such as CFSTR world examples.

Figure 7. Nurol Life Prejesi’nin tamamlanmış hali (Web Kaynağı-3)

4. CONCLUSION

We had the opportunity to observe many different engineering structures within the scope of this study. However, we could access limited information about the combination elements of these structures. We examined the advantages and disadvantages of the CFST construction style. We concluded that civil engineering is a very successful method in terms of safety, aesthetics and economy, which are the three basic elements of civil engineering, especially for high-rise buildings. Of course, good planning plays a key role in this success.

In today's world where the increase in the number of residences and the demand for tall buildings is increasing day by day, this application is an alternative to meet the needs. CFST elements can serve as a savior for bridges as well as building-type structures in situations where geographical conditions are unfavorable. It is possible to observe many similar examples. Concrete filled steel structures are at the top level in terms of convenience and frequency of use in composite systems. We believe that this demand will continue to increase depending on the population increase.

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WEB KAYNAĞI 2https://en.wikipedia.org/wiki/Petronas_Towers.

WEB KAYNAĞI 3 https://www.nurolgyo.com/tr/proje/nurol-life.html.