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Behaviour of Steel Concrete Composite Wall Panel Under Dynamic Loading

Shivamanjunathaswamy H G[1], Suman Patil[2], Kiran T[3]
[1]Research scholar, Dept. of Civil Engineering, UVCE, Bangalore University, Bangalore, Karnataka, India.
[2]M.Tech Student, Dept. of Civil Engineering, UVCE, Bangalore University, Bangalore, Karnataka, India.
[3]Associate Professor, Dept. of Civil Engineering, UVCE, Bangalore University, Bangalore, Karnataka, India.
Email ID: *sms.uvce@gmail.com[1], sumanpatil914@gmail.com[2], kirant.uvce@gmail.com[3]*

Abstract
The seismic behaviour of Structural elements are increasingly grasping attention in recent years. This paper presents the study of behaviour of Composite wall panel using Normal Conventional concrete (NCC) and Basalt fiber reinforced concrete (BFRC) by conducting Dynamic shake table test. The four different types of Composite Wall Panels(CWPs) are cast and experimental results are analyzed with Numerical analysis and finite element simulation method. The experimental results revealed that BFRC has higher mechanical properties compared to NCC. The dynamic test result shows displacement and damping vibration along with the changing of natural frequencies. Steel sheet BFRC Composite Wall Panels resist higher seismic motions compared to normal concrete wall panels. Analytical and numerical method was performed in order to evaluate the experimental results. From these results Basalt fiber can be used in the structural members to improve the tensile and ductility properties and also the behaviour of CWPs gives the seismic strength parameters of wall panels.

Keywords: *Composite Wall Panels (CWPs), Normal Conventional Concrete (NCC), Basalt Fiber Reinforced Concrete (BFRC), Out-of-plane, Shake Table Test, Seismic Behaviour.*

1. Introduction

As new trends in the building construction continue to emerge, the composite construction method is becoming more and more well-liked since it uses fewer resources and offers superior sustainability compared to the traditional concrete construction system [1]. A popular method for strengthening diaphragms is composite construction, in which two distinct materials are combined to provide a composite action. The shear motion between the steel sheeting and the hardened concrete is the force that drives the composite action of the walls. Composite constructions are referred to as structures made up of two or more different materials. In structural engineering, materials like concrete-timber, concrete-steel, and plastic-steel are often used. Composite construction combines the structural properties of both materials to build parts that are more rigid, stronger, and lighter by efficiently joining the two components. The two materials' shear-bond connection is necessary for them to work together as a single unit. Figure 1. displays the components of a composite wall(CPWs). Fiber addition to concrete can significantly improve its mechanical properties. Since fiber reinforced concrete (FRC) has good ductility, sufficient durability, and a fair degree of corrosion resistance, it is widely employed. In cement and concrete composite, fibers such as steel or biological fibers can be used. By adding basalt fiber, concrete's brittle failure mode can be changed to a non-brittle failure mode. In addition, it may be observed that there is strong bonding between basalt fiber and concrete by studying the failure characteristics of the fibers at the failure section. The petrochemical, construction, automobile, and aerospace fields all make a lot of these materials. When basalt is melted, no non-

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industrial waste, boron, or alkali metal oxides are released into the atmosphere, and the process of producing basalt fiber can begin without negatively impacting the environment [2].

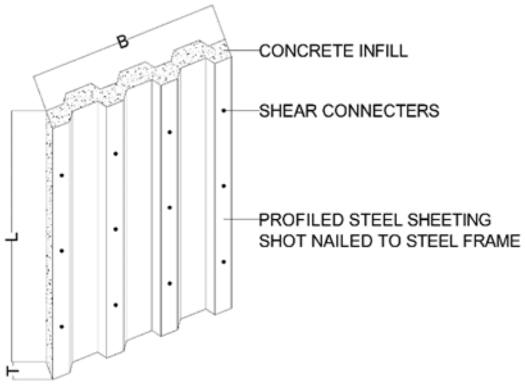

Figure 1 Elements of Composite Wall Panel

2. Detailing and Design of Composite Wall Panel

This study involves designing and casting wall panels, and then evaluating their dynamic behavior through experiments. The EN 1994-1-1 recommendations are followed in the design of wall panels. A cold-formed profiled steel sheet of length 700 mm, width 600 mm and thickness 1 mm are defined to do an experiment with composite panels. The Fig.2 shows the geometrical profile steel wall panel [3].

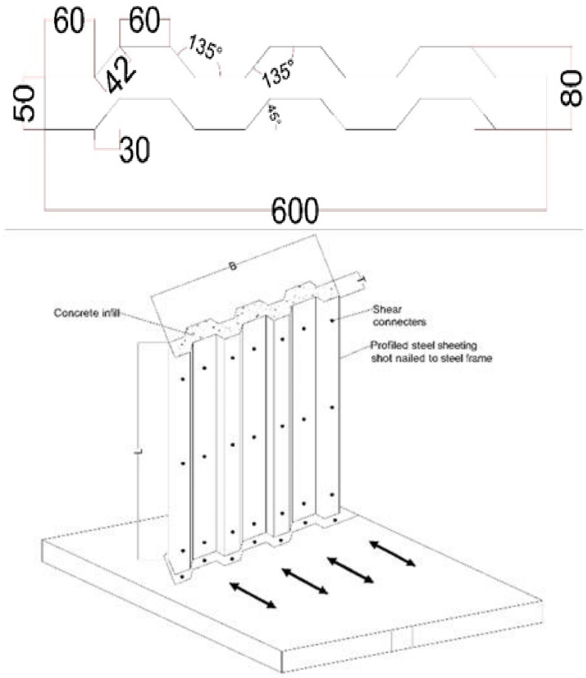

Figure 2 Geometrical Profile of Wall Panel

3. Materials

The characteristic compressive strength of M25 grade concrete has been achieved by casting Normal Conventional Concrete (NCC) and Basalt Fiber Reinforced Concrete (BFRC) in different kinds of composite wall panel (CWPs) [4].

Table 1 Type of Specimens

Sl. No	Specimens
01	NCC WALL PANEL (CCP-I)
02	BFRC WALL PANEL (CCP-II)
03	NCC COMPOSITE WALL PANEL (CWP-I)
04	BFRC COMPOSITE WALL PANEL (CWP-II)

4. Construction and Testing of Wall Panels

4.1. Design and Construction of the Specimen

The dimensions of the wall panel test specimens are 700 mm length, 600 mm width and 50mm thickness. Fig.3 displays the panel configuration. The compressive strength of M25 grade of concrete: NCC and BFRC are achieved 30.5N/mm2 and 33.02 N/mm2 respectively. A strong shear bond between steel and concrete is achieved by connecting the two profiled steel sheets with a shear connector made of 8 mm thick bolts that are spaced 100 mm apart from the top, bottom, and middle of the sheet. The composite wall panels with NCC and BFRC concrete are casted and cured. The test specimens are tested after 28 days of curing [5].

Figure 3 Composite Wall Panel (CWPs)

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4.2.Experimental Setup

The Experimental set-up of CWP are shown in Fig.4, procedure are as follows [6].

- The CWPs specimens are placed in Y-axis of the shake table 1 and shake table vibrates in the direction of X-axis to get out-of-plane values [7].
- Accelometers are placed at top and bottom of the Specimen to obtain the displacement, velocity and acceleration of the specimen. Fig 5 shows the accelometers and displacement disc [8].
- The gradual increase of frequencies is applied to the shake table and it is transferred to the composite wall panels and data to be collected from accelerometer and data acquisition system.

Figure 4 Experimental Setup

Figure 5 Accelometer and Displacement Disc

4.3.Result Observation on Test Specimen

The test specimens are exerted by shake table in the out-of-plane direction, which is perpendicular to the disc panel (i.e. along the X-axis of Shake table) under controlled frequency range between 0 to 20Hz. The displacement vs frequency graph of four different wall panels was obtained. The damping vibration are recorded for the four different types of wall panel. The stiffness is inversely proportional to damping ratio and recorded damping vibration results from the accelerating of wall panels are listed in Table.2 and damping vibration graphs are shown in Fig.6. The relation between Displacement and frequency obtained from the shake table are shown in Fig.7, Fig.8, Fig.9 and Fig.10. The numerical calculations of dynamic parameters are listed in Table.3. The comparison of displacement and frequencies of four different type of wall panels are shown in Fig.11. The equivalent Young's modulus is considered for composite structures in numerical analysis since it represents the mechanism of combining two materials into a unit composite action [9].

Table 2 Damping Ratio from the Shake Table Test

Specimen	Damping Ratio%
NCC Wall Panel (CCP-I)	5.87
BFRC Wall Panel(CCP-II)	5.52
NCC Composite Wall Panel (CWP-I)	4.53
BFRC Composite Wall Panel (CWP-II)	4.09

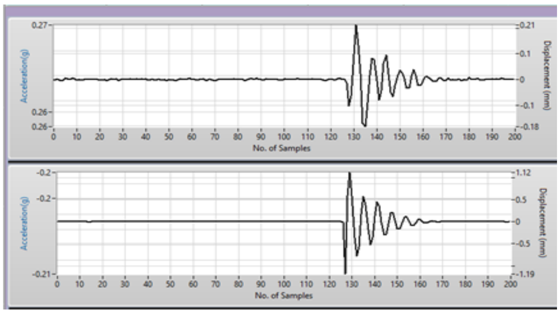

Figure 6 Recording of Damping Vibration

Table 3 Analytical Parameter Values

CWPs	Stiffness kN/m	Natural Frequency Hz	Critical Damping Co-Efficient Ns/m
CCP-I	1510.2	25.24	317.3
CCP-II	1570.5	25.74	323.58
CWP-I	1932.3	26.83	337.14
CWP-II	1990.0	27.42	344.68

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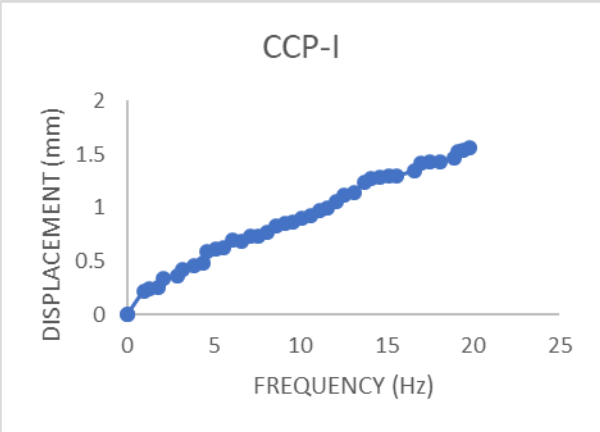

Figure 7 Displacement v/s Frequency of CCP-I

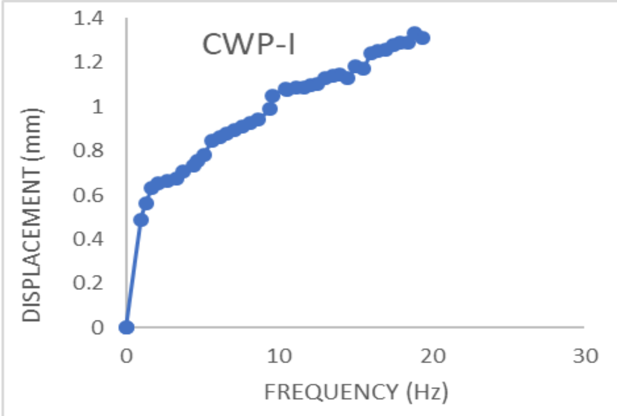

Figure 9 Displacement v/s Frequency of CPW-I

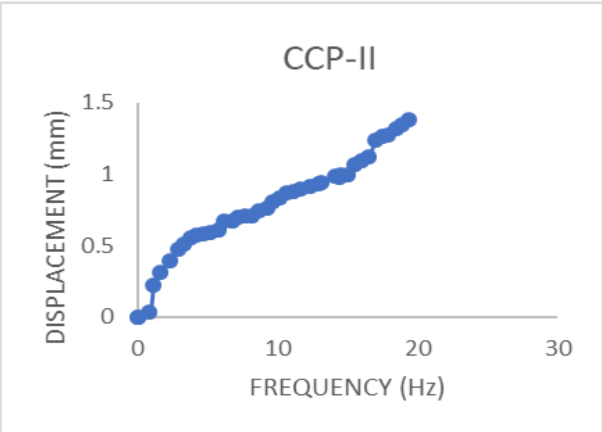

Figure 8 Displacement v/s Frequency of CCP-II

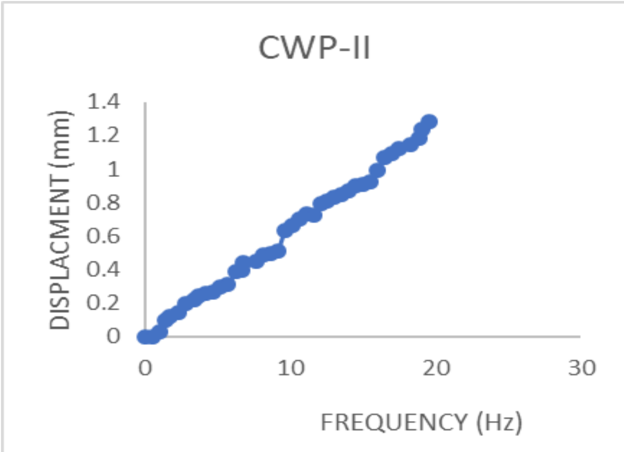

Figure 10 Displacement v/s Frequency of CWP-II

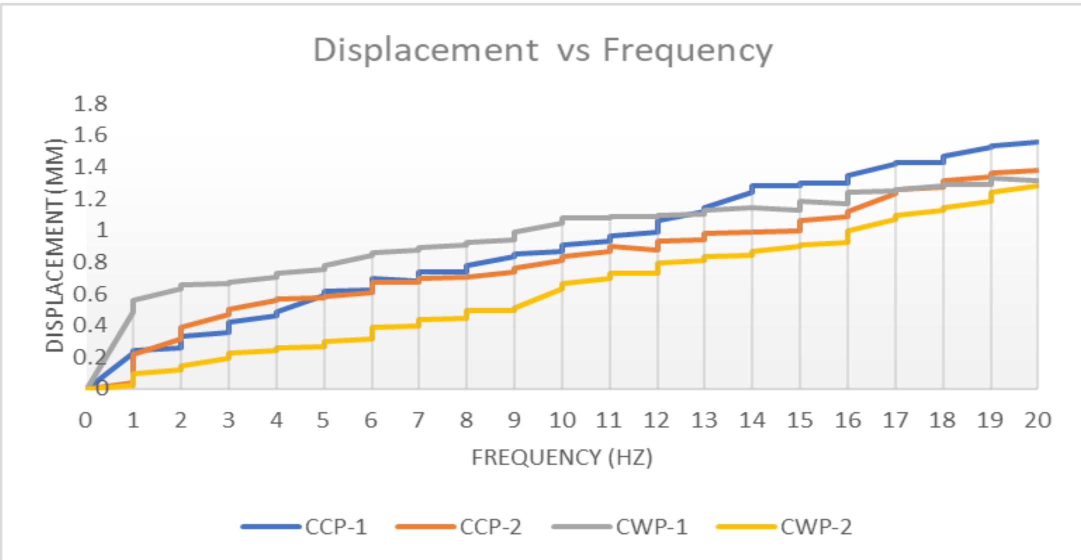

Figure 11 Comparison of Four Different Composite Wall Panels

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4.4.Numerical Analysis

Numerical analysis is done with simulation software and compared with the experimental results for better understanding the mechanism of CCP-I, CCP-II, CWP-I and CWP-II. The STAADPro software was employed for finite element(FE) analysis of the model which is subjected to dynamic effects from shake table test [10]. The models are created with surface plate and connected with fixed supports. The time-history analysis is employed for the computation and displacement response of CWPs. The modeling of specimen in STAADPro shown in Fig.12.

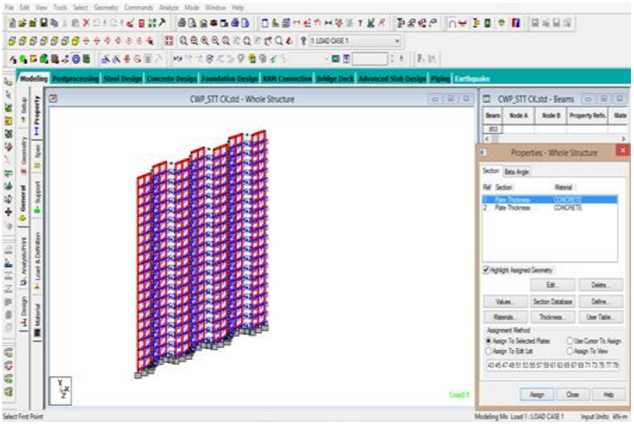

Figure 12 Model in STAAD-Pro

The displacements (Figures 14 & 15) obtained from the numerical analysis of four different CWPs are listed in Table 4 and the mode shapes of load cases are shown in Fig.13.

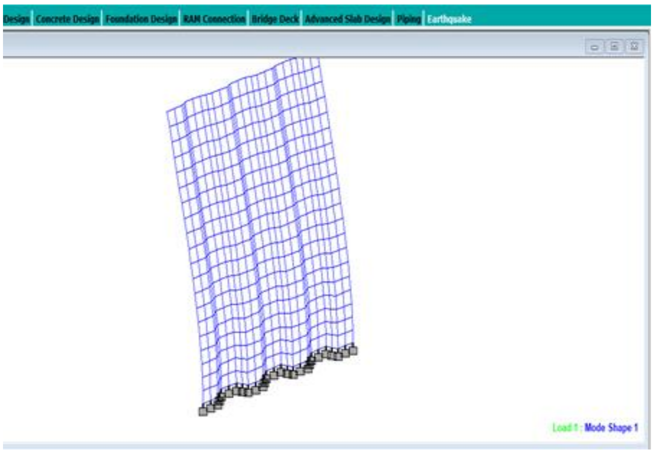

Figure 13 Mode shape of Model

Table 4 Displacement from the STAAD-Pro

Specimen	Displacement
NCC WALL PANEL (CCP-I)	0.659 mm
BFRC WALL PANEL(CCP-II)	0.474 mm
NCC COMPOSITE WALL PANEL (CWP-I)	0.421 mm
BFRC COMPOSITE WALL PANEL (CWP-II)	0.318 mm

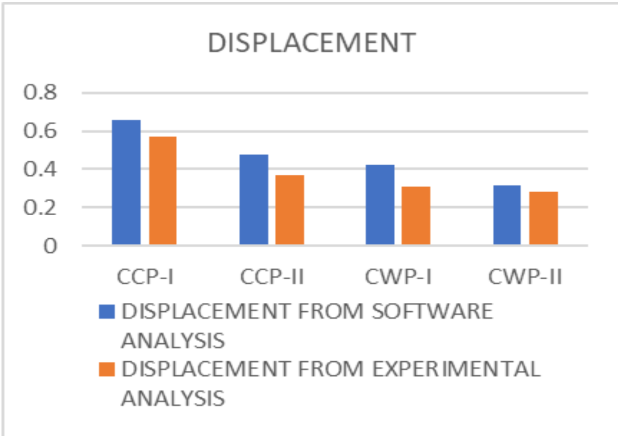

Figure 14 Displacement

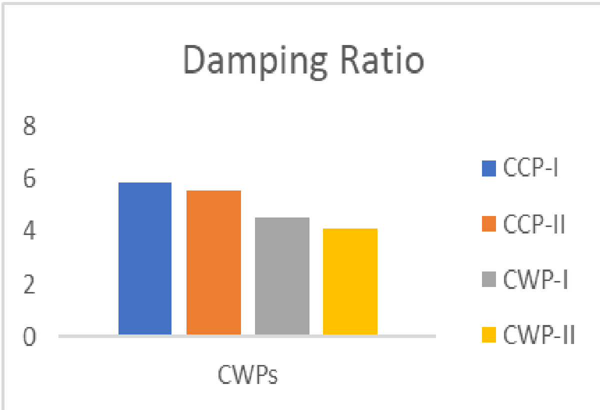

Figure 15 Damping Ratio

Conclusions

From this investigation studies, it is determined that adding basalt fibers to concrete can enhance its mechanical properties and improve the strength of structural elements like composite wall panels (CPWs) [11].

- The addition of 1% basalt fiber to the concrete mixture increases its strength by 6 to 8% over regular conventional concrete strength [12].
- The composite wall panels filled with BFRC (CWP-II) resists more series of seismic vibrations based on the displacement of wall panels acquired from the experimental and analytical program compared to composite wall panel filled with NCC(CWP-I).
- The damping ratio of the wall panels illustrates the stiffness of the walls CCP-I, CCP-II, CWP-I and CWP-II. Since the damping ratio and stiffness are inversely correlated. Compared to other wall panels, CWP-II is more rigid and having more stiffness.
- It is observed that the stiffness, strength and resistance of Basalt Reinforced concrete wall panel (CCP-II) was higher than that of conventional concrete wall panel (CCP-I).
- In comparison to conventional concrete wall panel (CCP-I), conventional concrete composite wall panels (CWP-I) has greater stiffness, strength, and resistance.
- It is noticed that the stiffness, strength and resistance of Basalt Reinforced concrete composite wall panel (CWP-II) was higher than that of Basalt reinforced concrete wall panel (CCP-II).
- From the observation it is concluded that basalt-reinforced concrete composite wall panels (CWP-II) has greater stiffness, strength, and resistance compared to concrete composite wall panels (CWP-I).

After analyzing the results, several kinds of composite wall panels using cold formed steel with shear connectors can be used/utilize in the mid high rise buildings and commercial buildings in the earthquake prone areas and military areas as it resists the seismic vibration. And also concluded that the Basalt fibres used in the concrete mixture will play the major roll in dynamic seismic effect of Composite wall panels.

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