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An Electromagnetic Pulse Shielding Effectiveness and Construction availability of the Cast-In-Place Structures Using Corrugated Metal-Plates

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Abstract

This study aims to examine the effectiveness of electromagnetic pulse shielding in cast-in-place protective shelters using the corrugated metal-plates and then reviews its usability in the Republic of Korea Army. The Korea Corps of Engineering has taken account of corrugated metal-plates as a construction material of cast-in-place structures which have to defend against mechanical impacts as well as electromagnetic pulses. A corrugated metal-plate is known as a superb mechanical protective material, so much so that it has been employed in ammunition magazines and artillery platforms in the armed forces. Moreover, as a metal, such as steel and copper, it is universally recognized as one of the most effective electromagnetic pulse shielding materials. In addition to effectively shielding from electromagnetic pulses and its protective capability from mechanical impacts, corrugated metal-plates should prove to be a competent construction material for the cast-in-place protective shelter in terms of construction availability and economic feasibility. The shielding effectiveness of suggested structures is examined along with MIL-STD 188-125-1. A few frequency bands need an increase of 15~30 dB in shielding effectiveness because of unbidden apertures caused by flaws associated with welding, assembling, and material deformation. However, allowing for around 40 dB of shielding effectiveness that soil can provide; the examined structure, which is buried underground, can offset its shortcomings sufficiently.

Keywords : electromagnetic pulse (EMP), shielding effectiveness, corrugate metal-plate, cast-in-place (CIP)

1. Introduction

1.1 Research objectives

Reinforced concrete is a main construction material to guarantee mechanical protectiveness, but is less competent as an EMP shielding material [1, 2, 3]. Steel is noted as a superlative material to attenuate an EMP, but is less reliable in terms of mechanical protectiveness because of its ductility [3]. Protective facilities are built to defend against mechanical impacts; nuclear, biological, and chemical contamination; and electromagnetic pulse (EMP) [1, 2]. So far, a few main C4I(Command, Communication, Control, Computer, and Intelligence) facilities provide an EMP protection [4]. However, it could be problematic to reinforce the EMP shielding functionon to less critical combat facilities or equipment because it is difficult to defray 30~40% additional expenses associated with EMP shielding beyond mechanical protectiveness [5, 6]. A corrugated metal-plate has been tested and proven to be a useful material in terms of mechanical protectiveness [3]. Furthermore, a steel-plate originally provides reliable shielding

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capabilities against an EMP [7]. This study aims to examine the electromagnetic pulse shielding effectiveness of cast-in place (CIP) protective shelters using the corrugated metal-plates and then review its usability.

1.2 Research significance and necessities

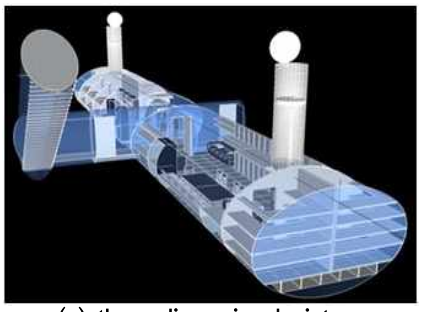
From the military aspect, current armed forces are based on information dominance, network-centric warfare, and expeditionary operations, which heavily rely on electronics or electric circuits. Thus, it will be likely that adversaries can use an EMP to employ asymmetric attacks [8]. From the civil aspect, it is impossible to operate banking, transportation, communication and so on across the board without electric devices, so it is inevitable to protect these social systems against an EMP which could be used to cause enormous social turmoil [4, 5, 6].

2. Literature reviews

2.1 Corrugated metal-plates structures

The representative construction methods associated with the EMP shielding are Modular Pan Type, Panel Type, and Welding Type [7]. These are additionally installed to block or attenuate EMP effects on the existing mechanical protective structures built with the reinforced concrete, so that the problems related to the cost and site-works cannot be ignorable [5, 6]. Due to these problems, it is hard to apply these methods on the protective structures for the small units such as a protective shelter. The CIP structures, at first, were used to protect isolated, small facilities or functional equipments from the main C4I buildings in both the US and USSR during the nuclear Cold War Era. One of the main advantages that CIP structures have is that it can, partially, get rid of the construction limitations which are caused by the cost, in particular, related to the site-works [6].

The Korea Corps of Engineering has taken account of a corrugated metal-plate as a construction material for the CIP structures as shown in Figure 1. A corrugated metal-plate is known as a superb mechanical protective material, so much so that it has been employed in ammunition magazines and artillery platforms in the armed forces. Moreover, as a metal, such as steel and copper, it is universally recognized as one of the most effective electromagnetic pulse shielding materials [7]. In addition to effectively shielding from electromagnetic pulses and its protective capability from mechanical impacts, corrugated metal-plates should prove to be a competent construction material for the cast-in-place protective shelter in terms of construction availability and economic feasibility.



(a) three-dimensional picture

(b) prototype

Figure 1. Cast-in-place structures

2.2 EMP Occurrence

A nuclear detonation is the most possible mode to generate an EMP. Gamma rays discharged by the explosion hit air molecules, so that free electrons, which are originally consisted of air molecules, are scattered and trapped in the magnetic field of the earth. These electrons generate an oscillating electric current which radiates the coherent EMP. While nuclear weapons mostly generate an EMP, it is also

related to high power microwaves and electromagnetic bombs [4, 5, 6, 7].

2.3 Electronic circuit vulnerability to EMP

Electrical and electronic devices or equipments could be wrecked by the EMP which effects are explained with rise time, electrical field strength, and frequency contents. In other words, an EMP induces large voltage and current transients on electrical conductors so that unhardened electrical and electronic circuits are devastated against ruinous and insuperable EMP rise time, field strength, and frequencies [4, 5, 6, 7].

2.4 EMP protection

EMP protection is defined with shield, grounding and bonding, and filtering. The shielding is usually associated with architectural fields, while the others are related to electric ones. The military and civil facilities should meet the shielding effectiveness requirements of MIL 188-125, MIL-STD 461F RS105; and ITU K.78(HEMP), ITU K.81(HEMP), and IEC SC 77C respectively. Continuous conductive enclosure is generally constructed with a metal, mostly steel and copper [7, 9].

3. Research Methodologies and Progress

3.1 Design and Manufacturing

The CIP structure was not redesigned but manufactured along with its original prototype as shown in Figure 2. However, the devices or equipment such as the shielding doors, honey-comb grills, wave-guided below cutoffs, and signal point-of-entries were assembled or welded, after being tested to see if they met the required standards on the MIL-STD 188-125-1.

3.2. Experiment

The frequency-dependent ration, expressed in decibels (dB), of the received signal when receiving antenna is illuminated by electromagnetic radiation in the test calibration configuration to the received

Figure 2. Manufacturing the cast-in-place structures using corrugated metal-plates

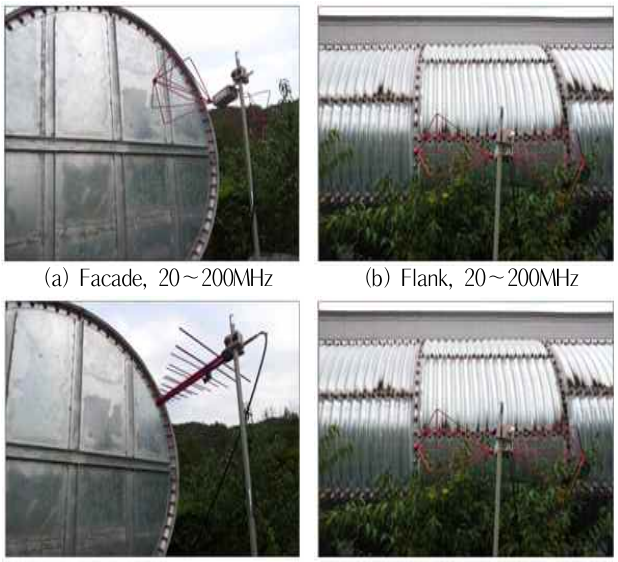
signal through the electromagnetic barrier in the test measurement configuration. Assuming the antenna voltage proportional to the field strength is detected:

$$SE = 20\log\left(\frac{V_c}{V_m}\right)$$

Where V_m is the measured signal at the test area, V_c is the calibration signal at the same frequency and transmitting antenna polarization, and corrections are applied for and difference in instrumentation system gain or attenuation between the calibration and measurement configurations. SE means the shielding effectiveness. Test frequencies shall be spaced approximately logarithmically within each decade, with minimum sampling density [7].

The experiments were performed along with the

MIL-STD 188-125-1 from two exterior sides for the calibration signal at the same frequency and transmitting antenna polarization as shown in Figure 3. The signals at the test areas, V_m are measured as shown in Figure 4.



(a) Facade, 20~200MHz (b) Flank, 20~200MHz

(c) Facade, 200Mhz~1Ghz (d) Flank, 200Mhz~1Gh

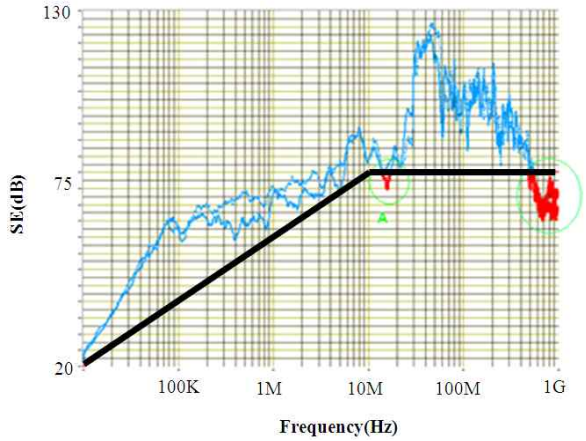
Figure 3. Experimental setups for measuring calibration signals

Figure 4. The experimental setup for measuring signals at test areas

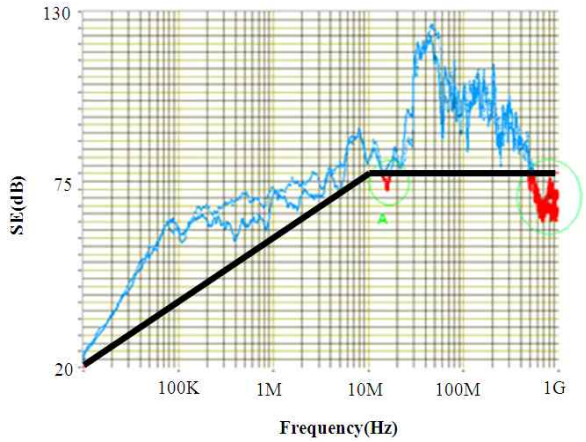
4. Results

The measured values should be above the straight, thicker line which means the minimum shielding effectiveness as shown in Figure 5.

A few frequency bands, in which measured shielding effectiveness is lower than the minimum requirement of MIL-STD 188-125-1, need an increase of 15~30 dB in shielding effectiveness because of unbidden apertures caused by flaws associated with welding, assembling, and material deformation as shown in Figure 6. However, allowing for around 40 dB of shielding effectiveness that soil can provide; the examined structure, which is buried underground, can offset its shortcomings sufficiently.



(a) Facade



(b) Flank

Figure 5. Shielding effectiveness of cast-in-place structures using corrugated metal-plates

(a) Welding (b) Assembling (c) Deformation

Figure 6. Apertures caused by welding, assembling, and

material deformation

5. Conclusion

CIP structures were designed and developed by the US and USSR in the 1970s. The main purpose of CIP structures in the armed forces are to provide protective shelter for the C4I equipment or troops which are isolated physically but connected functionally to the headquarters. The Republic of Korea Army, in particular, Korea Corps of Engineering considers the CIP structures using corrugated metal-plates, which are so advantageous in terms of structural strength, construction availability, and economic feasibility, as a protective shelter for small units or critical military electric or electronic circuits. Corrugated metal-plates have been already used in ammunition magazines and artillery platforms popularly thanks to its structural strength as a protective material. Furthermore, it is verified that the CIP structures using corrugated metal-plates contribute to save in construction costs up to 40% rather than the concrete facilities reinforced with metal-plates to attenuate the EMP.

In this study, shielding effectiveness for the CIP structures using corrugated metal-plates was examined along with the requirements and procedures shown in MIL-STD 188-125-1. According to the shielding effectiveness test, a couple of bands need an increase of 15~30 dB to meet the minimum requirement of shielding effectiveness. MIL-STD 188-125-1 asks that below-specification shielding effectiveness values do not be disregarded if it can be demonstrated that the reading is due to an ambient noise source that cannot practically be eliminated or the identified flaws which can be improved, when determining pass/fail. Considering more than 40 dB shielding effectiveness can be provided by the soil, the examined CIP structures using corrugated metal-plates, which are buried underground, are enough to offset its lacking in specific frequency bands. Consequently, it could be concluded that CIP structures using corrugated metal-plates afford to provide satisfactory EMP shielding effectiveness as well as be applicable to the EMP shelter.

Acknowledgement

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