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New Seamless Decorative Sound Absorbing Material——Environmental Friendly Sand Acoustic Panels

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ABSTRACT

Architecture indoor excessive sound reflections will increase noise and reduce speech intelligibility. In order to improve the sound quality of the environment, room surfaces, such as walls and ceilings, are often installed decorative sound-absorbing materials. Conventional absorbing materials always have segmented seams or resonance holes, designers would not achieve a large continuous, complete seamless decorative surface. Along with the arising of the post-modern design trends, new seamless decorative sound-absorbing materials are in need of development. In 2014, a new kind of environmental friendly panels which made of sand particles were developed successfully in Tsinghua, making China the second silicon polymerization techniques mastered country after Germany. Host material of sand acoustic panels is of silica inorganic, having natural advantages of physical and chemical properties: compressive strength 29.7MPa, combustibility rating A2, sound absorption coefficient 0.50-0.85, environmental friendly with water and acid endurance, surface no crack absolutely. There are dozens of applications cases in China, in this paper, an R&D auditorium of Baoding Great Wall Automobile is discussed in details.

Keywords: Acoustic sand panel, Seamless absorption, Speech intelligibility, Sound-absorbing materials decorative, Architectural acoustics Sound I-INCE Classification of Subjects Number(s): 35

1. BUILDING INTERIOR ACOUSTIC TREATMENTS

In buildings, sound contains both direct sound emitted by the source and reflecting sound reflected by walls, roofs, floors and other interfaces or other objects. Concrete, stone, glass, gypsum board or other hard surface materials, with reflectivity close to 100%, make sound-reflecting intense, resulting in long reverberation, high noise level, poor speech intelligibility, and bad sound environment.

There was a court judgment hall, using plaster boards as ceilings, stones as walls, marbles as floor, which excessive indoor reflection made its reverberation time up to 4-5 seconds. The judicial officer could not clearly hear what are saying, and even cause the clerk could not distinguish between "fourteen" or "forty" and erroneously recorded.

In order to reduce the interference of reflected sound, indoor surfaces should be designed to install sound-absorbing materials, not only to reduce reverberation for protecting speech intelligibility but also reducing noise for keeping quiet.

2. CONVENTIONAL SOUND-ABSORBING MATERIALS V.S. AVOUSTIC SAND PANELS

The applications of sound-absorbing materials are more than 100 years of history. Tradition decorative sound-absorbing material are divided into two major categories: one is fiber wool porous sound-absorbing materials, such as mineral wool, rock wool , glass fiber, wood wool panels, polyester fiber; Another is perforated panels, such as perforated aluminum panels, perforated gypsum boards, cement perforated boards, wood groove (perforated) panels. The advantages of traditional materials were low cost, moderate acoustic performance and acceptable decorative effect. However, these conventional sound-absorbing materials have weaknesses in decoration: always have segmented seams or resonance holes, designers would not achieve a large continuous, complete seamless decorative surface.

Post-modern design trends currently are exploding. Fashion designers have lost interests in fossil array tiles style with seams and holes everywhere, and they pay more attention to a new type of large,

irregular geometric surface seamlessly, emphasizing simplicity, personality and design sense. Bird's Nest, Water Cube, the National Grand Theater, New CCTV are all belong to the excellent post-modern design models which impressed people deeply.

In order to meet the growing requirements of post-modern decor, in the past 10 years, a new type of seamless decorative sound-absorbing material emerged, such as international brand Sto, Baswa, Fellert. Such new seamless sound-absorbing material has been widely used in theaters, museums, waiting lounges, offices, schools, restaurants and other public buildings, tightly combining simple decorative effect with quiet environment together. Outstanding works are: White House Press Office (see Figure 1), United States Dali Museum, Apple's flagship store in New York, the European Patent Office in Munich, Germany BMW Headquarters, Theatre in Germany Wiesbaden Music Academy (see Fig. 2), Brain Research Center in Las Vegas , and so on.

Figure 1 –White House Press Office（Fellert,ceiling and walls）

Figure 2 –Theatre of Wiesbaden Music Academy (Sto,walls)

Since 2010, architecture acoustic lab of Tsinghua University have been tracing this new seamless decorative acoustic materials, and associated industry companies successfully developed acoustic sand panels products which derive from mastering the core technology. An independent intellectual property rights (has obtained national patent) is finally available in China.

Figure 3 –Photos of acoustic sand panels

Within two years, this product has been successfully applied to Wuhu Fanta Wild theater, Tsinghua University Arts Education Center Theater, Tsinghua University Architeture School Lecture Hall, Baoding Great Wall Automobile R&D Center Auditorium, Conference Room of Benz Beijing Headquarters, Beijing Changping District Court Judge Hall, Beijing Changping Taikang Business School Lecture Hall (Fig. 4), Tsinghua University Teachers Dining Hall (FIG. 5) , and so dozens of types of complete projects.

Figure 4 –Taikang Business School Lecture Hall（walls）

Figure 5 –Tsinghua Teachers Dining Hall (curve ceilings and walls)

3. Acoustic Sand Panel Performances

Environmental friendly Sand Acoustic Panels are polymerized, the core technology is a silicon-based polymer. Silicon-based polymer is a new variant of the silica material. By chemical bond between the surfaces of the sand grains close to each other, sands outer surfaces welded together as polymerized to a hard, stone-liked panel. Due to the polymerization process keeping the gaps between the sand, a good porous sound absorption structure formed. Similar silicate-based cement (main ingredient is calcium silicate) also could chemically bond the sand grains together, but cement filled the gap between the sands, it became dense concrete which lost absorption effect. Similarly there is another silicate-based sodium silicate (commonly known as water glass) having abilities to bonded sand grains together, and to form a certain porose sand panel structure (such as cast iron sand mold), but sodium silicate is too water decomposition to use as building materials. Currently, the most mature technology of porose polymerization is silicon-based polymer technology.

Acoustic sand panels naturally have features of cheap, stable, fireproof, environmentally friendly, lovely texture by the advantages of sands and the polymeric silicon inorganic chemistry process. At the same time, panels also have a number of excellent performances, which are summary in table 1. All the indicators are tested by National CMA certification testing organizations:

Table 1 –Sand acoustic panel performances summary

Item		Test result	National requirements	Explaination
thickness	substrate	6 mm	/	This material is divided into substrate and surface layer. The substrate is a plate-like, frame-fixed layer on the wall or ceiling. The surface layer is a mortar-like plaster applied onto the outer surface of the substrate to form a continuous seamless decorative hard surface after drying. Both the substrate and the surface layer are made of sands with wealth of porosity (up to 45% -50%). Polymerization makes sand panels extremely strong, the compressive strength is close to C30 concrete. And other performances, such as rupture strength, pound resistance and nail holding, are better than the same thickness of cement board. Due to internal porosity, Sand panels are more adaptive to heating expanding and drying constriction, the finish faces are never cracked. Natural sand does not burn, which belongs to non-combustible A class. At high temperatures fire, sand particles would melt and drop off, so this panel was identified as non-combustible A2 class in laboratory fire testing. Almost be made of all natural inorganic material, it's free of formaldehyde, benzene and other harmful emissions, even better than ordinary paint or wallpaper.. After installation, you can employ the rooms immediately. Material PH value is neutral, so it's naturally durable of water, acid and alkali. Laboratory freeze-thaw cycle 25 times which simulate 25 years of extreme cold and heat cycles (one cycle: Full immersion in water, freezing below 0 ℃, then thawed and heating to a high temperature), the material strength is not less than 99% of the original strength. Sand acoustic panel's absorption coefficient is strongly related to sand particle diameter which can be optimized. By hundreds of absorption test with both different sand diameter ratio and the different porosity, ultimately the
	surface	3mm		
surfaces	substrate	9 kg/m2	/	
dencity	surface	4.5 kg/m2		
rupture strength		7.6 MPa	greater than 1.0 MPa	
compressive strength		29.7 MPa	greater than 10 MPa	
pound resistance		5.2 kJ/m2	/	
nail holding		>690 N	/	
combustion class		A2	A2	
TVOC emission		<0.062 mg	Less than 0.5 mg	
freeze-thaw cycle 25 times		Strength >99%	Strength greater than 90%	
absorption coefficient		0.50～0.85	NRC greater than 0.5	

best acoustic performance was determined.

4. CASE STUDY - GREAT WALL AUTOMOBILE R&D CENTER AUDITORIUM

Great Wall Automobile new technology R & D center is located in Baoding, Hebei Province, it's a multi-purpose lecture hall for conference, presentation, performances etc. It's 43.1 meters long, 27.5 meters wide, seating 1,500 people, interior volume of 8650m^3.

The lecture hall was designed in a modern simple interior style by a Germany architect, with large flat wall and seamless ceiling, giving audience a sense of permeability of bright visually. Acoustic designers assigned acoustic sand panels to meet with the requirements of both high absorption and seamless decoration.

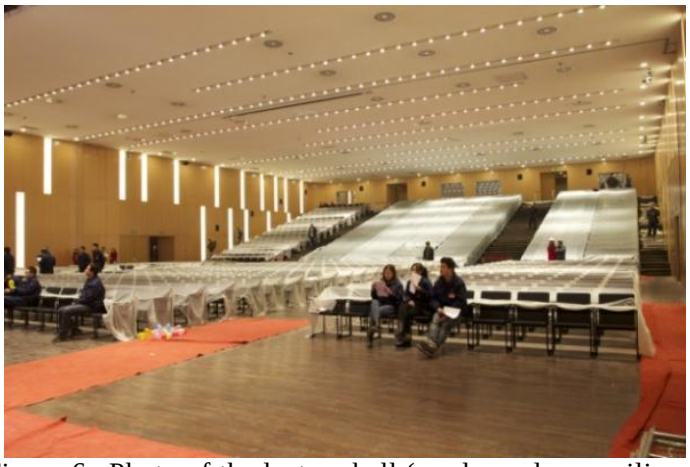

Figure 6 –Photo of the lecture hall (sand panels on ceilings)

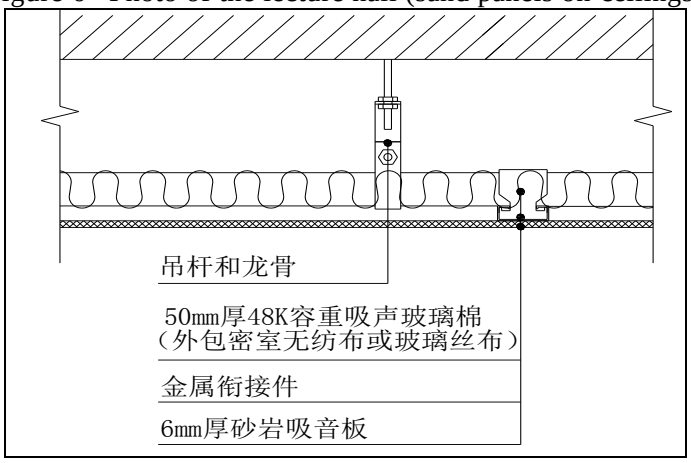

Figure 7 –Design details of ceiling construction

Table 2 –Absorption coefficient of the acoustic sand panel constructed ceilings

Freq（Hz）	125	250	500	1000	2000	4000
α	0.15	0.65	0.79	0.63	0.6	0.55

After constructions completed, reverberation time was tested，which value was about 0.9 seconds at 500Hz middle frequency (frequency characteristics are shown in Table 3), and the design objectives were all achieved.

Table 3 –Tested reverberation time (unoccupied)

Freq/Hz	125	250	500	1000	2000	4000
RT /s	0.98	0.94	0.91	0.88	0.79	0.62

Figure 8 –Indoor decorative effect of completion

5. Introduction of the author

Yan Xiang，PhD of architectural acoustics from the School of Architecture, Tsinghua University, now is the director of the architecture acoustic laboratory of Tsinghua University, head of architecture acoustic testing centre of Tsinghua University. He has been long engaged in scientific works for acoustics, noise control, acoustic test, acoustic simulation. Studies and projects on acoustic designs completed by him in recent years are: National Grand Theatre, 2008 Beijing Olympic venues (National Swimming Center, Laoshan Bicycle Racing Centre, National Stadium), Luoyang Sports Center, Daqing Cultue Center, Fujian Theater, Luoyang Theater, Jiangxi Grand Theatre, Beijing South Railway Station, the new Guangzhou Railway Station, the noise control of Jintan underground gas storage of nature gas West-East transmission , and so on. He presided over the translation of the book of “Guide of Architectural Acoustic Design (USA)”, and “Architecture Acoustics and Environmental Noise (Japan)”. He compiled and revised national standard of “Code for Measurement of Reverberation Time of Rooms”, and“ Acoustical Scale Model Measurement Specifications” and other national standards.