2. Nanotechnology

Table 1. Nanotechnological materials, application areas and expected benefits expanded from ee et al. (2010) .

Nanotech Materials	**Application Areas**	**Expected Benefits**
Nano Silica (SiO_2)	*Concrete*	*einforcement in mechanical strength*
	Ceramics	*Coolant; light transmission; fire resistant*
	indow	*Flame-proofing; anti-reflection*
Titanium Dioxide (TiO_2)	*Cement*	*apid hydration; increased degree of hydration; self-cleaning*
	indow	*Superhydrophilicity; anti-fogging; fouling-resistance*
	Solar cell	*Non-utility electricity generation*
Carbon Nanotubes (CNT)	*Concrete*	*Mechanical durability; crack prevention*
	Ceramics	*Enhanced mechanical and thermal properties*
	NEMS/MEMS	*eal-time structural health monitoring*
	Solar cell	*Effective electron mediation*
	Nano sensors	*eal time monitoring of structures*
Silver Nanoparticles (Ag)	*Coating/painting*	*Biocidal activity*
Copper Nanoparticles (Cu)	*Steel*	*eldability; corrosion resistance; formability*
Alumina	*Concrete*	*mproving mechanical and physical properties of concrete*
Fe_2O_3	*Concrete*	*increased compressive strength; abrasion-resistant*
Clays	*Asphalt*	*ncreasing the viscosity of asphalt binders and the fatigue strength of asphalt mixtures*
Quantum dots (CdSe)	*Solar cell*	*Solar Energy Utli ation*
Aerogels	*nsulation*	*Energy efficiency, space savings, moisture management, design flexibility*

Although nanotechnology has many benefits, exposure to nanomaterials is becoming one of the most significant risks in the workplace, particularly for the construction industry 11 . The effects of nanotechnological materials on the environment and human health are not clearly defined yet. There are some case studies on environmental exposure that apply construction nanomaterials. Their results indicate that certain levels of exposure are acceptable; for example, analysis of exposure when spraying self-cleaning coatings with nanoparticles of titanium dioxide (TiO_2) 11 . Another study evaluates exposure when making mortars with nanoparticles of irconium dioxide (rO_2). t concludes that the occupational limit values were not reached, but they were greater than the values for indoor air 12 . Exposure to materials during manufacturing and use may occur through three mechanisms: nhalation, dermal contact and ingestion. Minimal information is currently available on dominant exposure routes, potential exposure levels and/or material toxicity 13 . Although current knowledge on the toxicity of nanoparticles and the potential level of worker exposure is very limited, preliminary results in most of the important studies reveal significant biological activity and adverse effects 13 .

Table 2. illustrates examples of releasable nanomaterials that may pose ha ards on workers biological systems 14 . Table 2. also shows the possible existence of releasable nanomaterials in construction sites to enhance the uality and performance of construction materials without considering their possible undesirable health effects 15 .

Table 2. Examples of different nanomaterials and their toxicological impact on health 14

Possible Impact on Health	Nanomaterials	Possible Existence in Construction Sites
Damage, leakage, or thinning of the cell membrane	*Cationic nanoparticles*	*Cement, fasteners, coated surfaces, paint, flooring, H AC, and roofing construction materials*
Signaling cascade, cytokines, chemokines, and adhesion inflammations	*Cationic nanoparticles and carbon nanotubes*	
Mitochondrial damage including e-transfer, and ATP/PTP opening	*Cationic nanoparticles and ultrafine particles*	
Protein binding, unfolding responses, fibrillation, and loss of function	*Metal oxide nanoparticles and carbon nanomaterials*	
Oxidative stress injury, radical production, glutathione (GSH) depletion, lipid peroxidation, membrane oxidation, and protein oxidation	*Ultrafine particles, carbon nanotubes, metal oxide nanoparticles, and cationic nanoparticles*	
Fibrogenesis and tissue remodeling injury	*Carbon nanotubes*	
Blood platelet, vascular endothelial, and clotting abnormalities	*Silica (SiO2)*	

Note: e-transfer = electron transfer; PTP = permeability transition pore

3. Conducting survey

[illegible]

[illegible]

excluded from the evaluation.

4. Survey results and discussion

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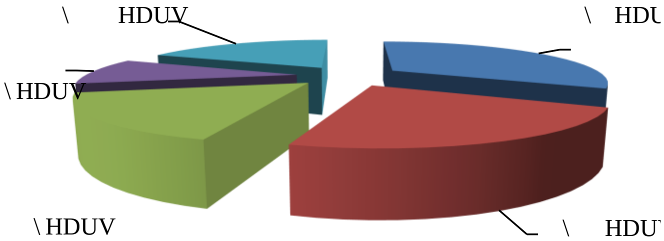

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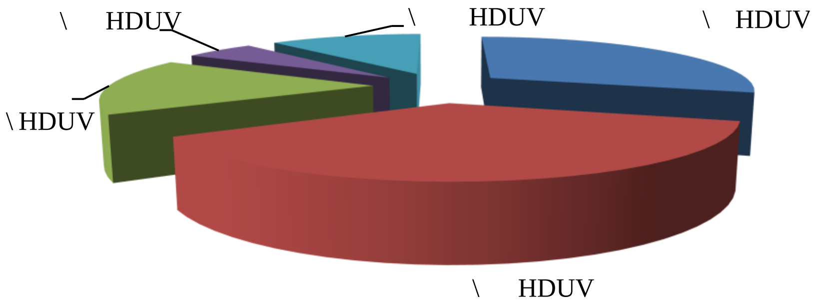

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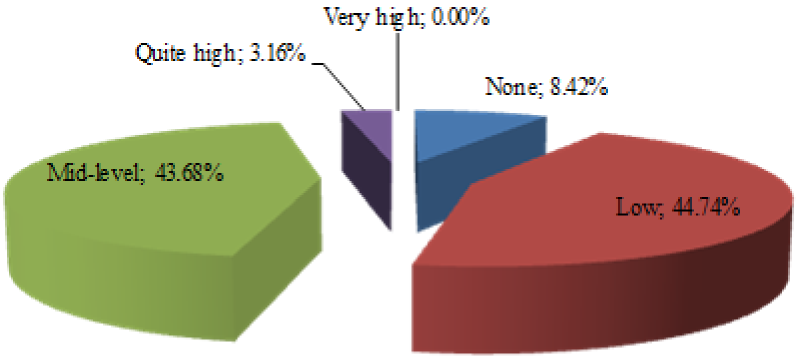

Figure 3. espondents knowledge levels in nanotechnology

Figure 4 shows the nanotechnological building materials used by the firms. t is found that approximately 60 of firms (58.95) do not use nanotechnological building materials at all. On the other hand, the study shows that the first three most used nanotechnological building materials are; (ECT) ceramic nanomaterials (20.53), self-cleaning coatings/paints (17.37) and fire protection nanomaterials (16.32).

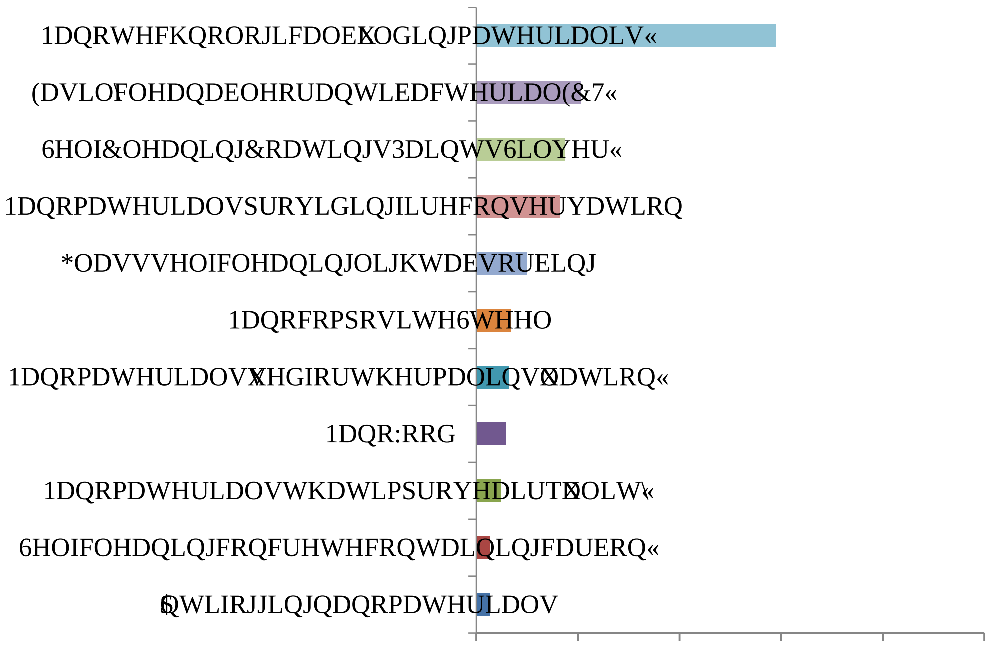

Figure 4. Nanotechnological materials used in the sector

The large number of architectural design firms that have not used nanotechnology (58.95) shows that the developments in nanotechnology are not closely watched by architects. Even though, the nanotechnological developments have attracted the academic community by many rational solutions; the increasing usage of nanotechnological new materials and devices can only be reali ed by understanding the *relationship between value engineering and technological developments 5 . Figure 5 demonstrates the factors that prevent the architects from using nanotechnological building materials extensively.*

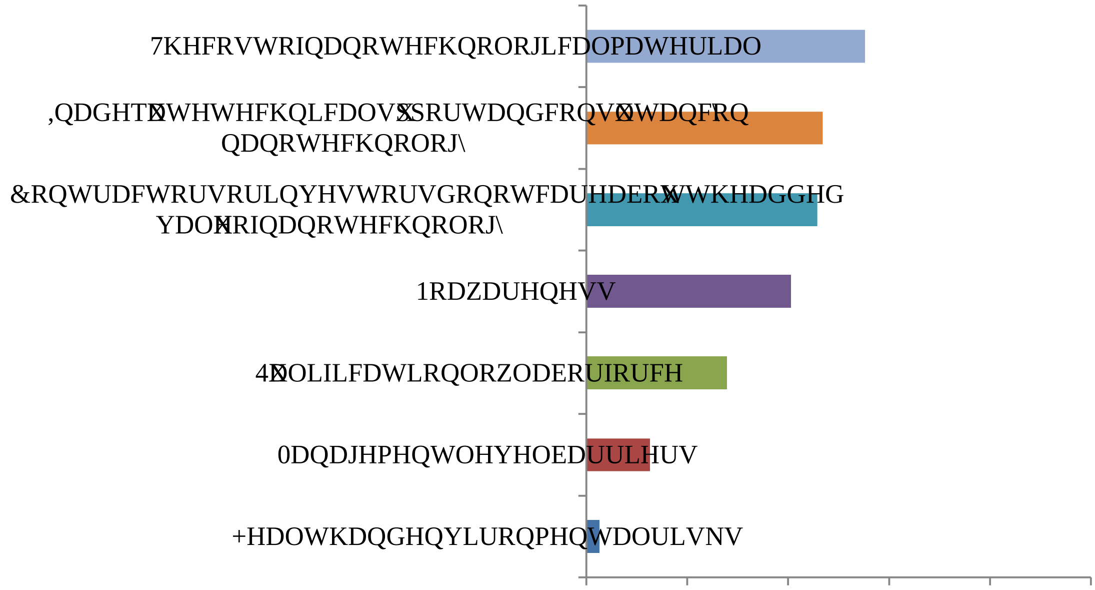

Figure 5. Factors affecting widespread use of nanotechnological materials

Survey shows that; the factors affecting the widespread use of nanotechnological materials are mainly the cost of nanotechnological materials (55.26), the lack of technical support and consultancy in nanotechnology (46.84), and the importance of contractors or investors to the added value of nanotechnological materials (45.79).Several problems and challenges persist and hinder the widespread use of nanomaterial incorporation in the construction industry. These include the absence of mechanical property data, lack of construction experience, and cost of construction 16 .Major construction companies and main contractors are not familiar with nanomaterials, their characteristics and effectsNanotechnological materials are considerably more expensive than non-nanotechnological alternatives. According to Broekhui en et al. (2011), high costs are one of the major obstacles to widely acceptance of nanotechnological materials in the sector 17 . Sectoral adaptation of nanotechnological building materials is slow due to the incompatibility between the high cost of nanotechnology products and short-term financial benefits compared to traditional construction materials 18 . According to Scalisi (2017) nanotechnology does represent a relatively recent accomplishment and prices are destined to fall, as is usually the case, over the course of time, with all new technology 19 . Expectations are that costs will decrease over time, as manufacturing technologies improve and demand increases 20 . The low investment in research in the construction industry is another major obstacle to nanotechnology usage. The skepticism of the end -user and the lack of awareness of architects about new materials are other obstacles for the widespread usage of new materials in the construction industry. The use of this technology is not only aimed at improving the properties of conventional materials, but also at monitoring the health and safety of structures and the energy consumptions 18 . According to Hanus and Harris (2013) note that, adoption of nanotechnological products is often hampered by limited product awareness within the industry, the conservatism of the construction industry, and the commonplace focus on up-front build costs over long-term cost, performance, sustainability and safety 10 . Figure 6. shows whether architectural firms are investing in nanotechnology or not.

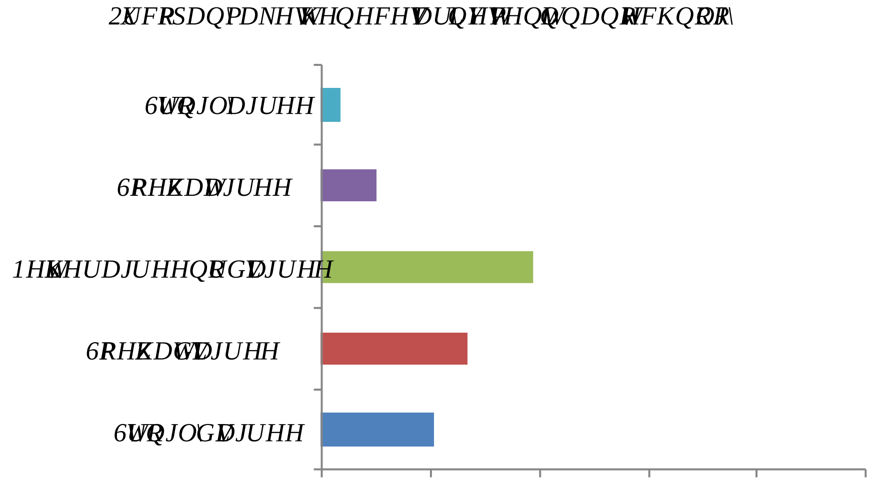

Figure 6. nvestment in nanotechnology

Nanotechnology has found application in the construction industry and there are some nano products in the market. However, the use of these products is almost negligible. Today, about 1 of building-related products have nano-enriched properties. Since the construction sector is not a technology-oriented, it can be concluded that D investments are in very low level. Figure 7. shows whether there are nanotechnology experts or research groups at the firm.

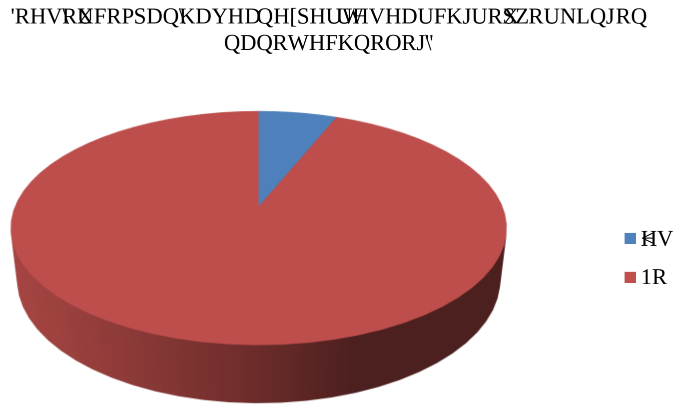

Figure 7. Expert / esearch group on nanotechnology existence in participating companies

5. Conclusions

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functions, but also in the context of energy saving. ess fossil fuel use can be achieved by using high performance thermal insulation materials. Thermal insulation applications reduce the amount of energy used to create comfort conditions and prevent global warming and air pollution. New materials increase the performance of buildings and use of energy is decreasing. The maintenance and repairs become easier since the operating costs are reduced. The various effects of nanotechnological materials on the environment and human health are not clearly defined yet. More studies needed about that.

The construction industry should be considered as one of the strategic sectors where nanotechnology can be applied. Ensuring the university-industry cooperation will increase the possibilities of technology transfer. Nanotechnological materials can increase the competitiveness of companies, since sustainability and energy efficiency become a necessity at present. The number of companies producing and using nanotechnology is very limited in Turkey. Nanotechnology research centers are established in universities. National nanotechnology policies have been identified in the many of EU member countries. mportant steps have been taken in nanotechnology area in Turkey, and the construction industry must be supported with incentives. Also, ensuring the sustainability of established research centers is vital.

References

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