Research Journal of

Environmental Sciences

ISSN 1819-3412

Academic
Journals Inc.

www.academicjournals.com

Research Journal of Environmental Sciences 3 (3): 384-391, 2009
ISSN 1819-3412

Demolition Agent Selection for Rock Breaking in Mountain Region of Hyrcanian Forests

Aidin Parsakhoo and Majid Lotfalian
Department of Forestry, Faculty of Natural Resources,
Sari Agricultural Sciences and Natural Resources University, Islamic Republic of Iran

Abstract: In this study, the AHP and Expert choice software were used for data analysis. The criteria to be used for selecting agents were determined and then scorings were done with authorized engineers. Results indicated that the priorities of the various demolition agents in the case of laminated schist stone was hydraulic hammer>expansive chemicals>dynamite>CARDOX>rock cracker and for dry sandstone, limestone, marl was rock cracker>CARDOX>expansive chemicals>dynamite>hydraulic hammer. Also, the alternatives were arranged as rock cracker>CARDOX>dynamite>hydraulic hammer>expansive chemicals for moist sandstone, limestone and marl. To conclude, this study reveals that decision-making methods can be used in the process of selecting demolition agent for the rock breaking.

Key words: Demolition agent, rock breaking, decision-making, AHP, Hyrcanian mountain

INTRODUCTION

In mountain region of the Hyrcanian forests of IR-Iran, road building is difficult due to larger quantities of stones and rocks (Woltjer *et al*., 2008; Parsakhoo *et al*., 2008a). Thus at these regions, rock breaking is frequently performed by use of explosive agents with traditional methods of blasting such as dynamite and non-explosive demolition agents such as expansive chemical materials, rock cracker, CARDOX and rarely hydraulic hammer. Then the bulldozer and hydraulic excavator are used to remove broken stones. The detonation of non-explosive matters in the holes is for protection of the trees in adjacent zones, since it avoids the throwing around of rocks (Whitney and Stowers, 1885; Sarikhani and Majnonian, 1994; Parsakhoo *et al*., 2008b).

Rock breaking technologies and equipment has developed after 1960 in Romania which led to important changes in this field of forest roads building. From 1966 to 1985 the carbides, Ferro-alloys rods, Mobile compressor for energy production with compressed air at 8-10 atm, Drills and electric drills and pneumatic hammers with a productivity of 3 m h^{-1} with 2 hammers were used for rock breaking (Asmarandei and Cazan, 1996; Aleksandrova and Sher, 1999).

The CARDOX system of rock breaking was perfected in the UK many years ago and has been used extensively throughout the world on major projects and projects where certain sensitivities need to be considered. These include environmental, cultural, heritage and urban areas where very little disturbance or pollution may be tolerated. CARDOX uses electrically charged compressed Carbon Dioxide (CO_2) gas to gently heave, rather than explode or blast rock, making the job quicker, safer and more cost effective, consequently optimizing their own environmental and safety policies, Because CARDOX system does not use explosives in any way and noise, vibration and dust is controlled (Singh, 1998; Dey and Ramcharan, 2008).

Corresponding Author: Majid Lotfalian, Department of Forestry, Faculty of Natural Resources, Sari Agricultural and Natural Resources University, Badeleh, Sari City, P.O. Box 737, Mazandaran Province, Islamic Republic of Iran
Tel: +98 152 4222984-5 Fax: +98 152 4222982

Chemical demolition agents such as KATROCK, DEXPAN and FRACT.AG are highly expansive powder compositions for stone breaking, non toxic chemicals and environmentally friendly, safe, controlled demolition agent used as an alternative to blasting. Chemical non-explosive demolition agents are mixed with clean water and poured into pre-drilled holes on rock and concrete. The holes are often prepared by pneumatic hammer. The diluted non-explosive demolition agent swells and exerts significant expansive thrust on the hole-wall. After a certain period, the pressure induced by the chemical non-explosive demolition agent fractures the wall and splits the rock across the line of the drill holes. These chemicals easily split and fracture mass rock without producing any noise, vibration, toxic gases or flying debris (Murray *et al*., 1994).

The rock cracker is a non-explosive rock-splitting tool that makes use of the technology of motive force. After the borehole is drilled, it is filled with water and the cracker cartridges and tee-piece are inserted. After firing mechanism, the stone is split successfully into several pieces with the rock cracker, without requiring a blasting license (Ginzburg, 1999).

The hydraulic hammer mounts on backhoes or excavators for demolition work. The hammer of this equipment has various shape and size. Moil, chisel and blunt are the most important drill attachments of the hydraulic hammer for demolition and boulder breaking process. The moil is a standard tool for almost any application. The moil point is ideal for general use in demolition (Haarlaa, 1973; Voitsekhovskaya, 1974; Tunçdemir, 2008).

When using a multiple criteria decision-making method, the criteria that will affect the selection should be determined beforehand. The most important factors for selecting the demolition agents for forest roads construction in Hyrcanian Mountains are environmentally pollutions, purchasing, transporting and preparing cost and demolition power. The basic principle in demolition agent selection is to define the degree of priority or governing factors among the ones given above and then determining the matching demolition agent and the alternatives to these parameters comparatively (Coulter *et al*., 2006; Sanchidrian *et al*., 2007).

The objectives of this research were to select the best demolition agent for breaking the three types of stones (i) moist sandstone, limestone and marl (ii) dry sandstone, limestone and marl and (iii) laminated schist stone in mountain regions of the Hyrcanian forests of IR-Iran with the analytical hierarchy process (AHP) and Expert choice software.

MATERIALS AND METHODS

Rocks are divided to three groups (1) Igneous rocks, (2) Metamorphic rocks and (3) Sedimentary rocks. Metamorphic rock usually derived from fine-grained sedimentary rock. Individual minerals in schist have grown during metamorphism so that they are easily visible to the naked eye. Schists are named for their mineral constituents. For example, mica schist is conspicuously rich in mica such as biotite or muscovite (Motamed, 2000). Sedimentary rocks are classified by the source of their sediments. Sandstones and limestones are examples of sedimentary rocks (Fig. 1) (Folk, 1965; Blatt and Tracy, 1994).

Fig. 1: Different types of stone or rock (a) limestone, (b) sandstone and (c) schist

AHP developed by Saaty (1980), is a method that enables reaching a decision by using quantitative and qualitative data. As the problem is stated in the hierarchical tree structure in this method, the problem becomes easy to understand. A hierarchical tree comprises a minimum of three stages: target, criteria and alternatives. Use of this method is widespread in mining and geology. AHP is based on determining the relative priorities (weighting) of the criteria by pairwise comparison. In pairwise comparison, the question is asked that 'how many times is a criterion more important than another one?' and it is answered according to the scale in Table 1. For controlling the consistency of comparison, the consistency ratio is determined. Firstly, the consistency index (T_i) of the matrix is determined by Eq. 1:

$$T_i = (\lambda_{max} - n)/(n-1) \quad (1)$$

where, λ_{max} is the maximum value and n is the size of matrix. The random consistency index (R_i) is obtained by Eq. 2:

$$R_i = 1.98\,(n-2)/(n) \quad (2)$$

The consistency ratio is determined by the T_i/R_i ratio. If the ratio is below 0.1 this shows the comparison is consistent (Acaroglu *et al*., 2006; Aykul *et al*., 2007). Lastly in AHP, the normalized eigenvectors created by the scoring of the alternatives considered for each criterion are turned into a matrix and this matrix is multiplied with the normalized eigenvector, including the weights of the criteria. The result gives the preference values of the alternatives. In this study which was conducted in July 2008, the Expert choice software was used for selection of demolition agent. Our criteria were environmental pollution of agents, their cost advantages and demolition power. Also, our alternatives were chemical demolition agent, rock cracker, CARDOX, dynamite and hydraulic hammer (Fig. 2). Required data were gathered through pairwise comparison questionnaires filled by forest engineers (Fig. 3).

Table 1: Scale for pairwise comparison

Definition	Degree of importance
Equal	1
Moderate	3
Strong	5
Very strong	7
Extreme	9

2, 4, 6 and 8 can also be used

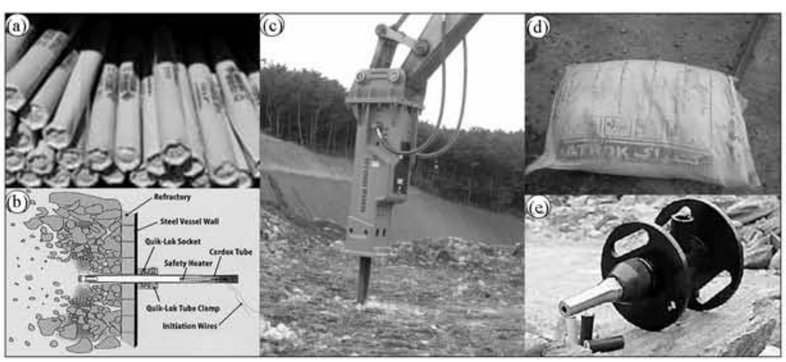

Fig. 2: Different types of explosive and non-explosive demolition agents (a) dynamite, (b) CARDOX, (c) hydraulic hammer, (d) expansive chemical materials and (e) rock cracker

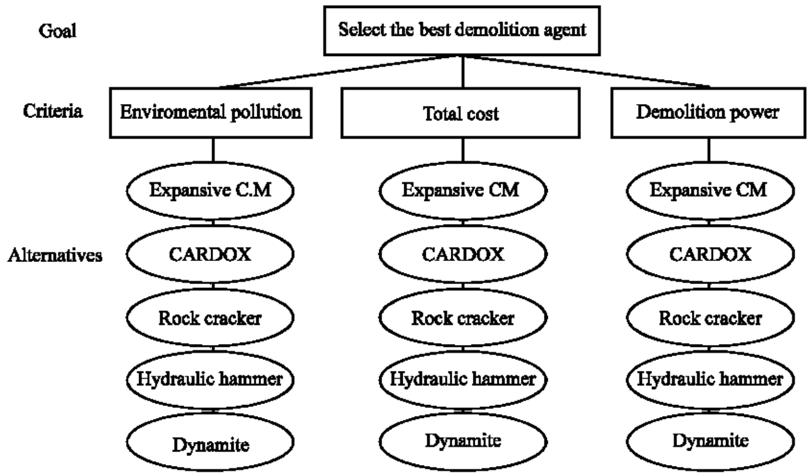

Fig. 3: AHP decision support hierarchy

RESULTS AND DISCUSSION

Table 2 and 3 explains the cost of the demolition agents and their environmental pollution. The pairwise comparison of alternatives according to cost and environmental pollution (criterion) was done with Saaty (1980) scale and the normalized eigenvectors of obtained matrices were calculated (Table 4, 5). Table 6, 7 and 8 shows pairwise comparison matrix of alternatives for the different stones. Also, pairwise comparison matrix of criteria has been shown in Table 9.

The values of alternatives for environmental pollution are given in Fig 4a. The dynamite (w = 0.034) and hydraulic hammer (w = 0.082) had more environmental pollution than the other agents because of throwing of broken stones and noise pollution during blasting (Whitney and Stowers, 1885; Tunçdemir, 2008). The use of expansive chemicals (w = 0.463), dynamite (w = 0.304) and rock cracker (w = 0.142) were more commodious than CARDOX (w = 0.046) and hydraulic hammer (w = 0.046) (Fig. 4b). Expansive chemical materials had lowest demolition power in moist sandstone, limestone and marl (w = 0.028) (Fig. 4c). This problem was also observed for rock cracker (w = 0.033) (Fig. 4d) in laminated schist stone and was observed for hydraulic hammer in dry sandstone, limestone and marl (w = 0.033) (Fig. 4e).

After rack cracker, the CARDOX had highest demolition power in breaking the moist or dry sandstone, limestone and marl. The CARDOX system consists of a high-strength reusable steel tube filled with liquid carbon dioxide (CO_2) that is energized with a small electrical charge. Expanding up to 6,000 times the original volume, the CO_2 is released through a discharge nozzle, creating a powerful pushing force reaching pressures up to 34,000 psi. More than three tons of blockages can be dislodged by a single blast in milliseconds (Singh, 1998; Dey and Ramcharan, 2008). Environmental pollution (w = 0.731) was most important factor influencing the demolition agent selection in hyrcanian mountain forests (Fig. 4f).

Lastly, according to the AHP, the normalized eigenvectors obtained by scoring the alternatives according to each criterion were turned into one matrix and this matrix was multiplied by the normalized eigenvector, including weights of the criteria (Acaroglu *et al*., 2006; Aykul *et al*., 2007). As a result of this operation in the Expert choice software, the values of alternatives (demolition agents) for types of stones are given in Table 10.

Table 2: Demolition agents costing in US dollar based on 2007 prices

Type of demolition agent	Delivered price	Unit cost
Expansive chemical material	1.09 ($/kg)	1.09 ($/kg)
Rock cracker	10869 $	43.48 ($/hole)
CARDOX	32608 $	86.96 ($/hole)
Dynamite	3.26 ($/kg)	3.26 ($/kg)
Hydraulic hammer	11000 $	38.04 ($/hour)

Table 3: Assessment of the environmental pollution of demolition agents

Type of demolition agent	Noise	Vibration	Safety	Throwing of broken stones
Expansive chemical material	There is not	There is not	High	There is not
Rock cracker	Very low	There is not	High	There is not
CARDOX	Very low	There is not	High	There is not
Dynamite	Very high	High	Low	Very high
Hydraulic hammer	Medium	Low	High	Very low

Table 4: Alternatives pairwise with respect to environmental pollution

Best fit	CARDOX	E. chemical material	Hydraulic hammer	Dynamite
Rock cracker	1	1	5	7
CARDOX		1	5	7
E. chemical material			5	7
Hydraulic hammer				5

Table 5: Alternatives Pairwise with respect to cost advantage

Best fit	Dynamite	Rock cracker	CARDOX	Hydraulic hammer
E. chemical material	2	4	7	9
Dynamite		3	6	7
Rock cracker			5	3
CARDOX				1

Table 6: Alternatives Pairwise with respect to demolition power in dry sandstone, limestone and marl

Best fit	CARDOX	Dynamite	Hydraulic hammer	E. chemical material
Rock cracker	3	4	6	9
CARDOX		2	4	8
Dynamite			2	7
Hydraulic hammer				6

Table 7: Alternatives Pairwise with respect to demolition power in moist sandstone, limestone and marl

Best fit	CARDOX	Dynamite	Hydraulic hammer	E. chemical material
Rock cracker	3	5	7	9
CARDOX		3	5	7
Dynamite			3	5
Hydraulic hammer				3

Table 8: Alternatives pairwise with respect to demolition power in laminated schist stone

Best fit	E. chemical material	Dynamite	CARDOX	Rock cracker
Hydraulic hammer	3	5	7	9
E. chemical material		3	5	7
Dynamite			3	5
CARDOX				3

Table 9: Pairwise comparison matrix of the criteria

Best fit	Demolition power	Cost
Environmental pollution of agents	5	7
Demolition power		3

Table 10: Final results of the AHP for different types of stones

Type of stone	Chemical materials	CARDOX	Rock cracker	Hammer	Dynamite
Dry sandstone, limestone and marl	0.271	0.273	0.311	0.064	0.081
Moist sandstone, limestone and marl	0.033	0.262	0.513	0.063	0.129
Laminated schist stone	0.322	0.030	0.027	0.406	0.215

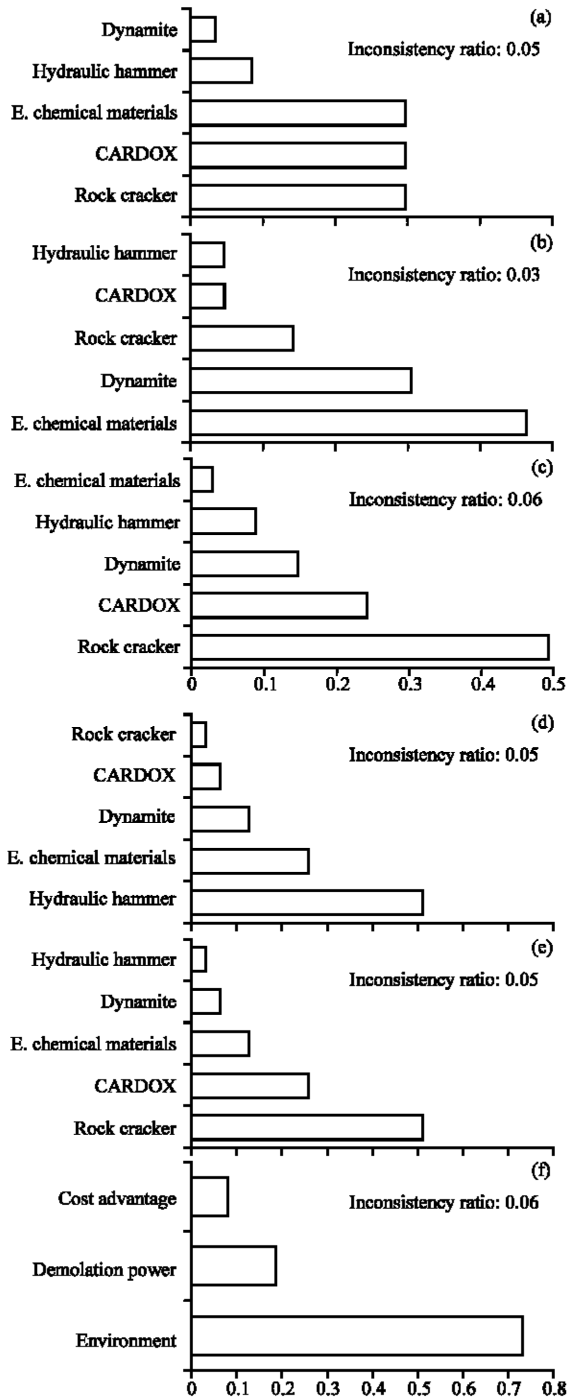

Fig. 4: (a) Derived priorities with respect to environmental advantages, (b) derived priorities with respect to cost advantages, (c) derived priorities with respect to demolition power in moist sandstone, limestone and marl, (d) derived priorities with respect to demolition power in laminated schist stone, (e) derived priorities with respect to demolition power in dry sandstone, limestone and marl and (f) weights of the criteria

Therefore, the priorities of the various demolition agents in the case of laminated schist stone was hydraulic hammer>expansive chemicals>dynamite>CARDOX>rock cracker. These priorities for dry sandstone, limestone and marl were rock cracker>CARDOX>expansive chemicals>dynamite> hydraulic hammer. Also, the alternatives were arranged as rock cracker>CARDOX>dynamite> hydraulic hammer>expansive chemicals for moist sandstone, limestone and marl.

CONCLUSION

Demolition agents have been used extensively in rock breaking operations. Their selection should be made correctly in known rock and project properties. Some serious problems may occur as a result of wrong selections and the production will be affected negatively. The multiple criteria decision-making methods can be used in various fields of forest engineering where there are ambiguities in the selection of demolition agents for the rock breaking in mountain region of Hyrcanian forests. By using these methods, some conflicting criteria can be evaluated together and scoring can be done by considering the properties of the region and the requisites.

This study reveals that the most suitable blasting agent for breaking the laminated schist stone was hydraulic hammer. When hydraulic hammer is not available, expansive chemicals are used for breaking large rocks. Also, dry or moist sandstone, limestone and marl are better destroyed by rock cracker. In traditional blasting methods by dynamite, the dislocated rock is thrown around chaotically and causes excessive damage to the environment. So it was recently forbidden by the forestry authorities of northern forest of Iran. Explosive and non-explosive techniques and material that do not damage environment must be used while road passing on rocky areas.

REFERENCES

Acaroglu, O., H. Ergin and S. Eskikaya, 2006. Analytical hierarchy process for selection of roadheaders. J. South Afr. Institute Min. Met., 106: 569-575.

Aleksandrov, N.I. and Y.N. Sher, 1999. Effect of stemming on rock breaking with explosion of a cylindrical charge. J. Min. Sci., 35: 483-493.

Asmarandei, M. and I. Cazan, 1996. Building and Maintenance of Forest Roads Technologies and Equipment. FAO, Rome, pp: 291-300.

Aykul, H., E. Yalcin, I.G. Ediz, D.W. Dixon-Hardy and H. Akcakoca, 2007. Equipment selection for high selective excavation surface coal mining. J. South Afr. Institute Min. Met., 107: 195-210.

Blatt, H. and R.J. Tracy, 1994. Petrology: Igneous, Sedimentary and Metamorphic, Freeman. 2nd Edn., Cambridge University Press, New York, ISBN: 0-7167-2438-3.

Coulter, E.D., J. Sessions and M.G. Wing, 2006. Scheduling forest road maintenance using the analytic hierarchy process and heuristics. Silva Fenn., 40: 143-160.

Dey, P.K. and E.K. Ramcharan, 2008. Analytic hierarchy process helps select site for limestone quarry expansion in Barbados. J. Environ. Manage., 88: 1384-1395.

Folk, R.L., 1965. Petrology of Sedimentary Rocks. 2nd Edn., Hemphill's Bookstore, Austin, ISBN: 0-914696-14-9.

Ginzburg, É.S., 1999. Combined steel-hard alloy outfitting of rock-breaking drilling tool. Chem. Petroleum. Eng., 35: 725-729.

Haarlaa, R., 1973. Maaston vaikutuksesta metsäteiden rakennukseen (On the effect of terrain on forest road construction). Silva Fenn., 7: 284-309.

Motamed, A., 2000. General Geology. Tehran University, Iran, ISBN: 964-03-3571-1, pp: 477.

Murray, C., S. Courtley and P.F. Howllett, 1994. Developments in rock-breaking techniques. Tunn. Undergr. Sp. Technol., 9: 225-231.

Parsakhoo, A., S.A. Hosseini, H. Jalilvand and M. Lotfalian, 2008a. Physical soil properties and slope treatments effects on hydraulic excavator productivity for forest road construction. Pak. J. Biol. Sci., 11: 1422-1428.

Parsakhoo, A., S.A. Hosseini, M. Lotfalian and H. Jalilvand, 2008b. Bulldozer and hydraulic excavator traffic effect on soil bulk density, rolling project and tree root response. Int. J. Natural Eng. Sci., 3: 139-142.

Sanchidrian, J.A., P. Segarra and L.M. Lopez, 2007. Energy components in rock blasting. Int. J. Rock Mech. Min., 44: 130-147.

Sarikhani, N. and B. Majnonian, 1994. Forest roads plan, performance and utilization guide line. Publ. Program Budget Org. Iran, 131: 159-175.

Satty, T.L., 1980. The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation. McGraw-Hill Inc., New York, ISBN: 0070543712, pp: 19.

Singh, S.P., 1998. Non-explosive applications of the PCF concept for underground excavation. Tunn. Undergr. Sp. Technol., 13: 305-311.

Tunçdemir, H., 2008. Impact hammers applications in Istanbul metro tunnels. Tunn. Undergr. Sp. Technol., 23: 264-272.

Voitsekhovskaya, F.F., 1974. A high-power hydraulic drill for breaking hard rock. J. Min. Sci., 10: 599-604.

Whitney, W.A. and J.H. Stowers, 1885. The dynamite explosion in westminster hall. Lancet, 125: 363-364.

Woltjer, M., W. Rammer, M. Brauner, R. Seidl and G. Mohren, 2008. Coupling a 3D patch model and a rockfall module to assess rockfall protection in mountain forests. J. Environ. Manage., 87: 373-388.